Basic Rail Vehicle Suspension Parameters

Presented by:
Gary Wolf

Wolf Railway Consulting
2838 Washington Street
Avondale Estates, Georgia 30002
404-600-2300
www.wolfrailway.com

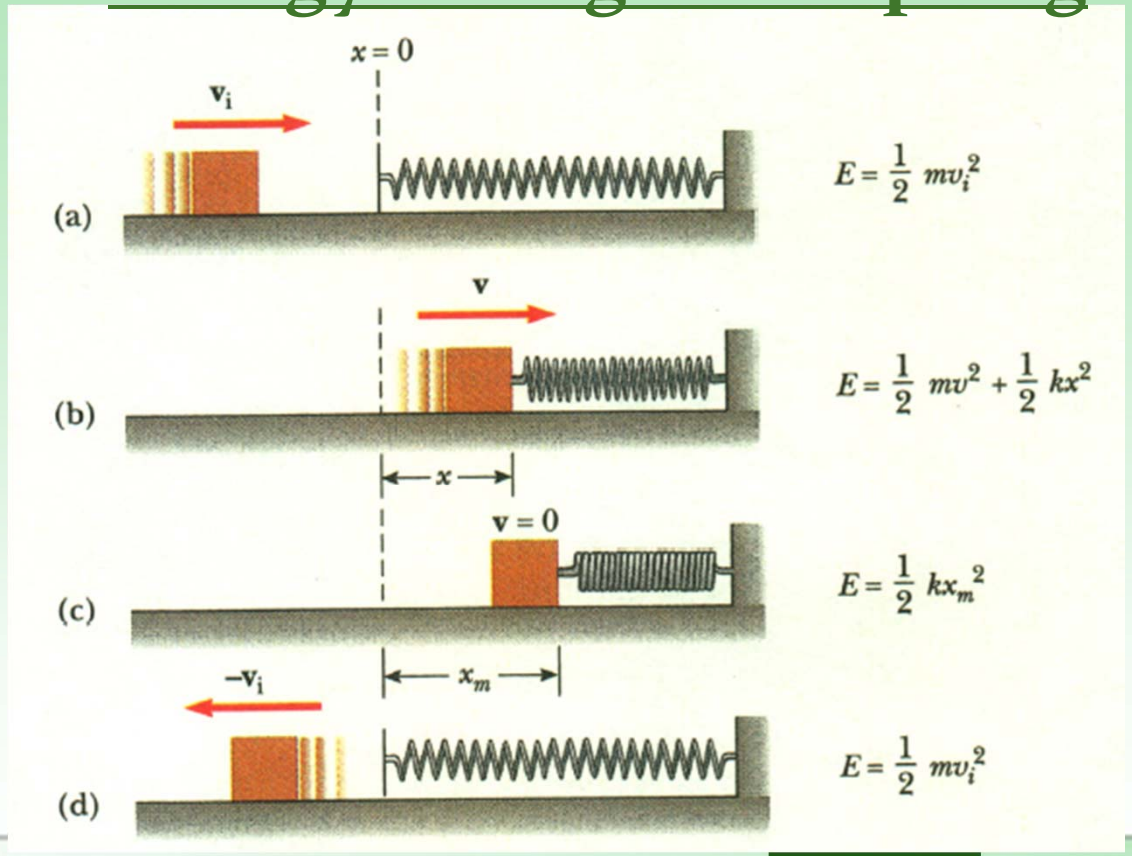
Rail Vehicle Suspension Agenda

- 3 Primary Suspension Modes
  - Lateral, vertical, yaw/warp
- Freight Cars
  - Springs and friction dampers
  - Yaw mode and truck warp
- Passenger/Transit Cars
  - Springs and dampers
  - Lateral suspensions
- Locomotives

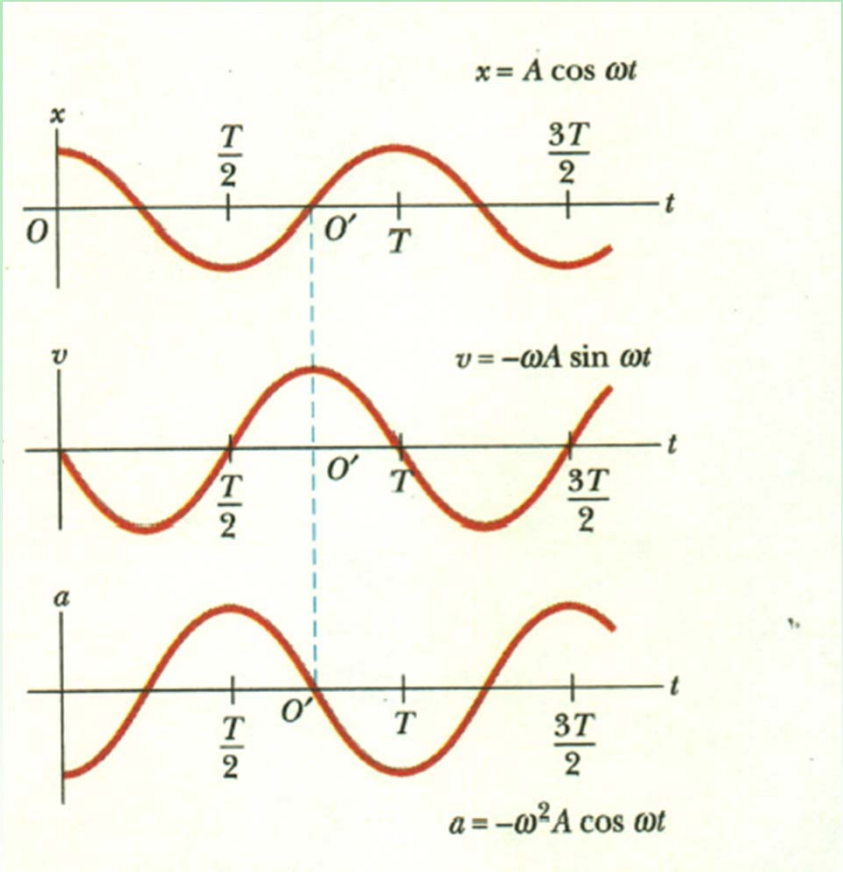
Primary Role of Suspension

- 1. Absorb vertical and lateral road shocks from perturbations in the track. Springs are used to slow down the accelerations over time, and store the energy.
- 2. Dissipate the energy stored in the springs to prevent it from amplifying the motions of the road shocks and returning the energy back to the car. Dampers are used to dissipate the energy.

Energy Storage in a Spring



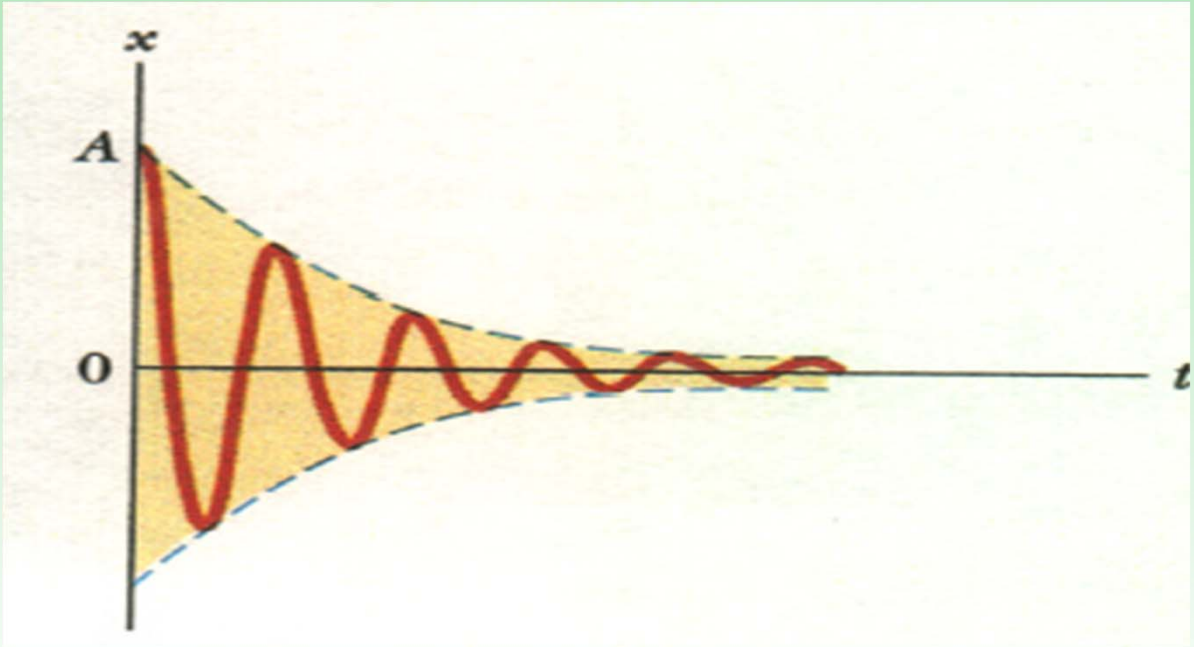
Typical Motion Response of an Undamped Spring



Displacement

Velocity

Acceleration



Motion Response of a Damped Spring

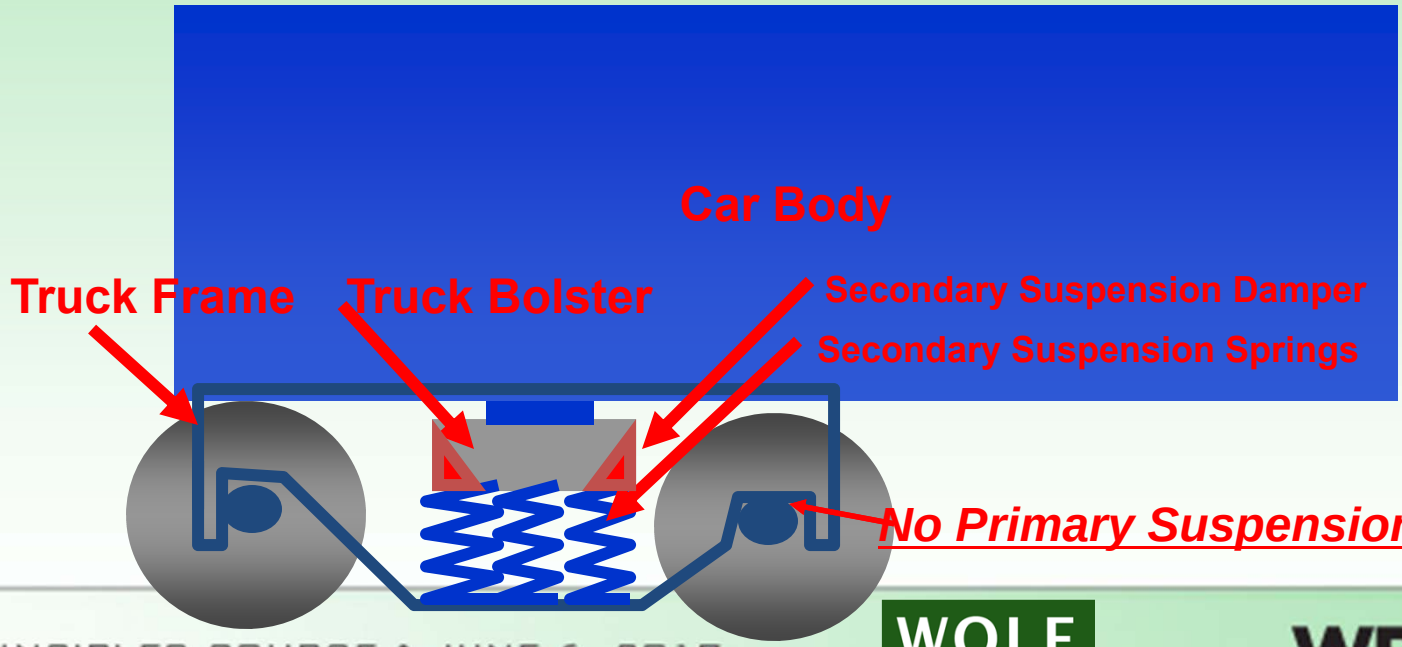
Vehicle Suspension Elements - 3 Principal Modes

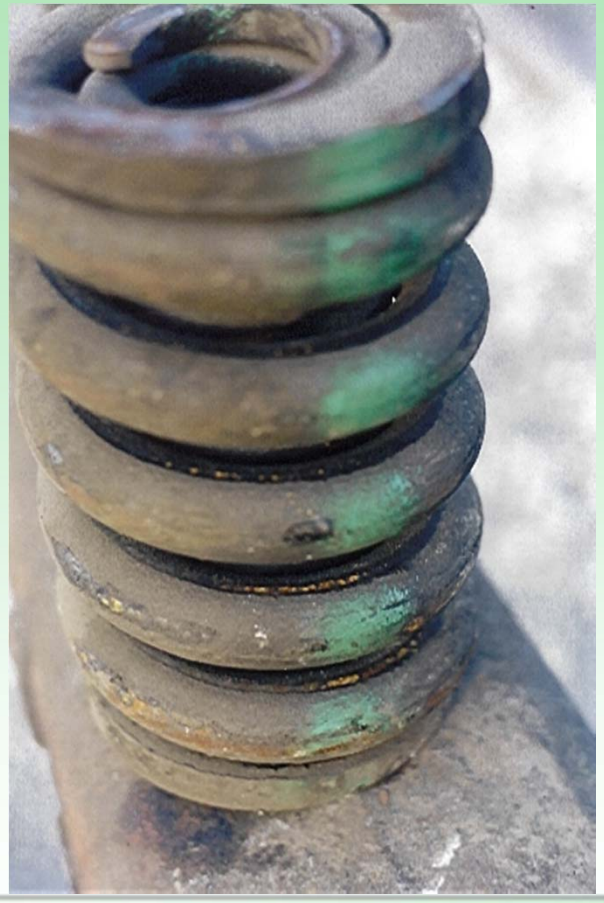
- Vertical Suspension
- Lateral Suspension
- Yaw/Warp Suspension

Vertical Suspension

- **Freight Cars**
  - Secondary suspension springs between truck frame and bolster
  - Friction snubbers between frame and bolster
  - No Primary suspension
- **Passenger/Transit Cars**
  - Primary suspension between wheelset and frame
  - Secondary suspension between frame and bolster, or frame and body
- **Locomotives**
  - Primary and secondary elements

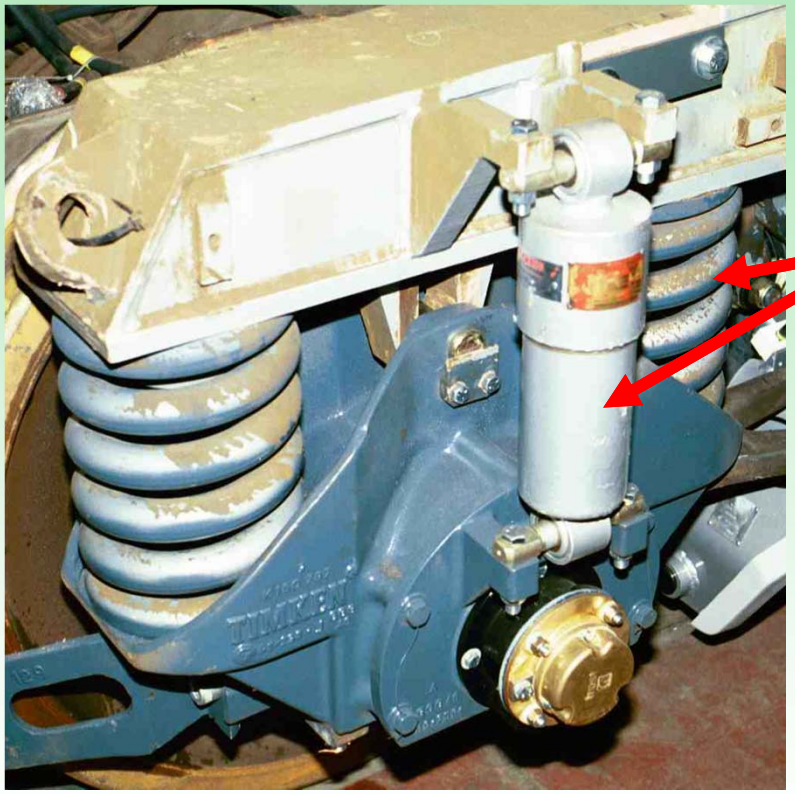
Major Bodies
Freight Cars





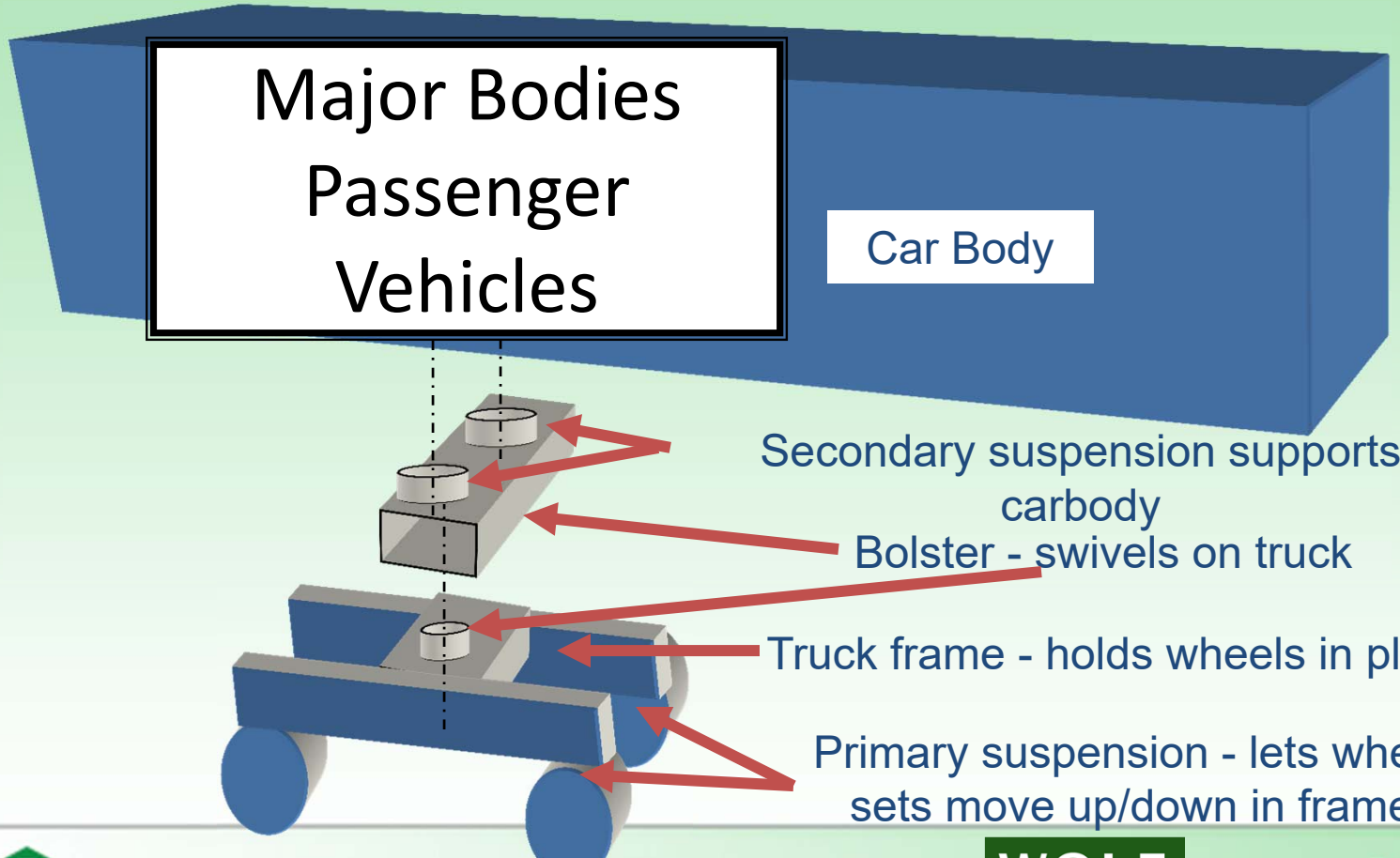
Spring: An Energy Storage Device

Damper: Dissipates Energy

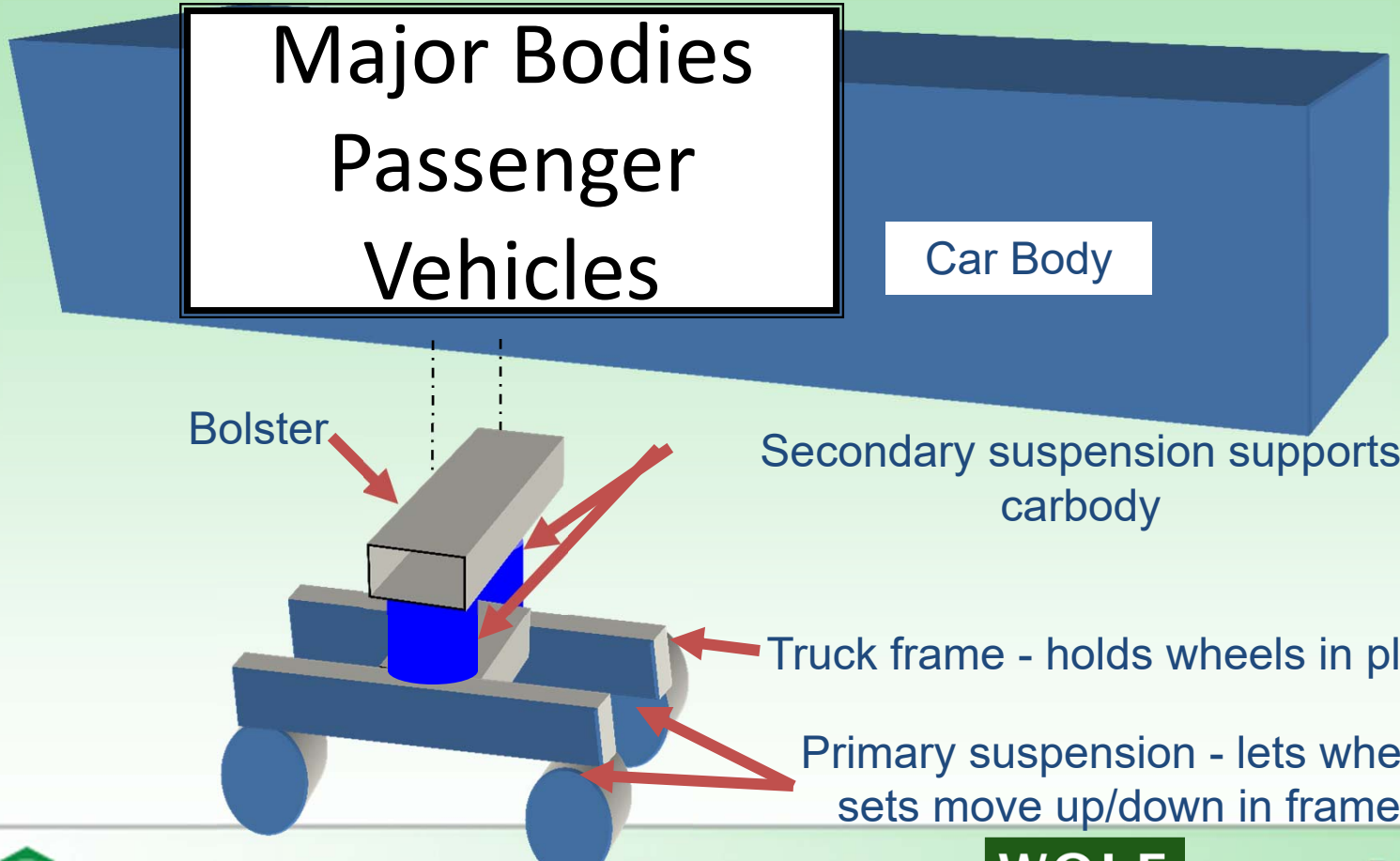


Springs and Dampers Working in Parallel

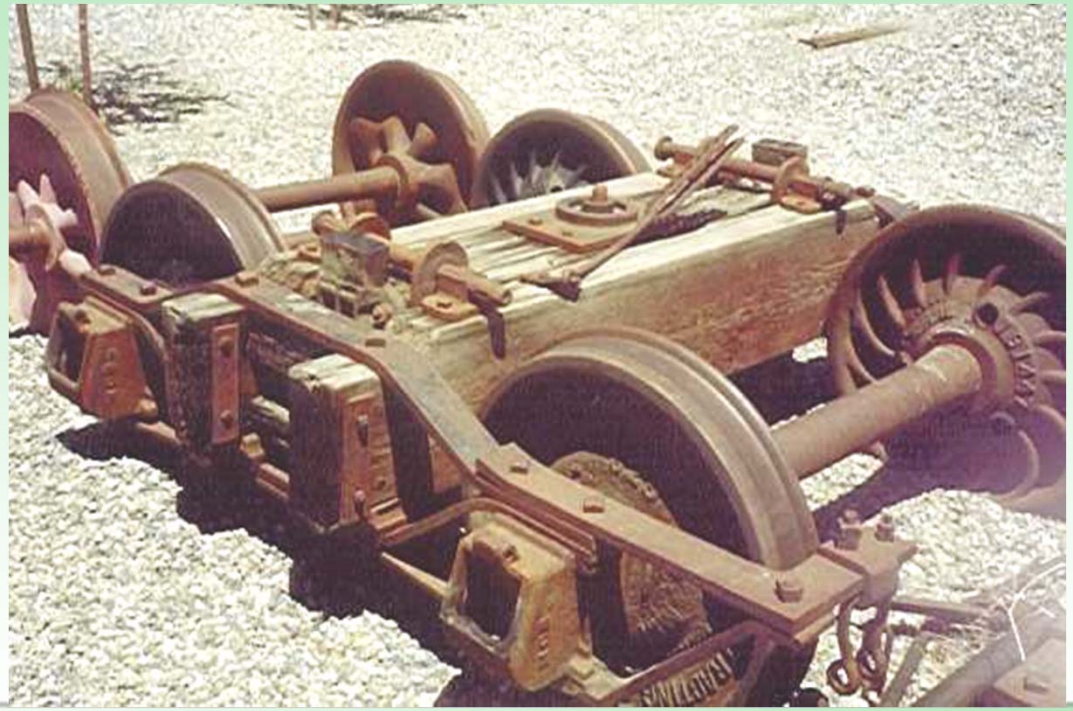
Major Bodies Passenger Vehicles

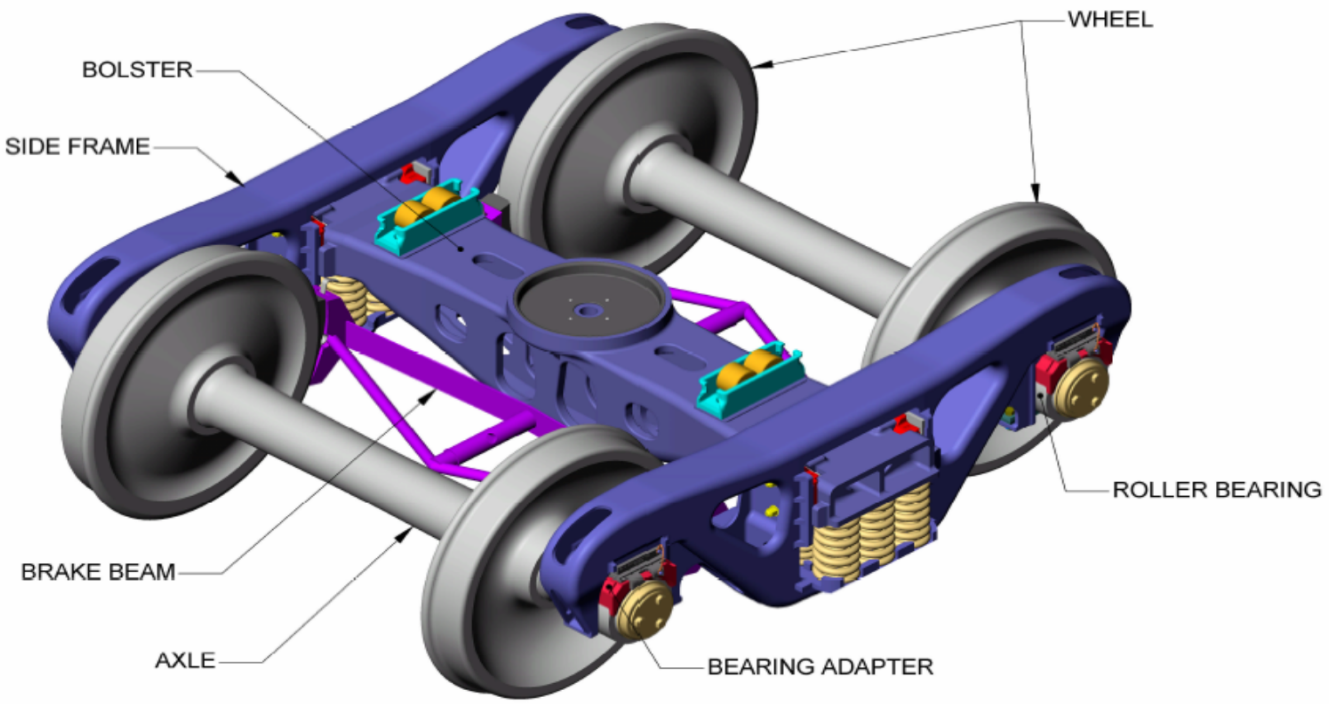


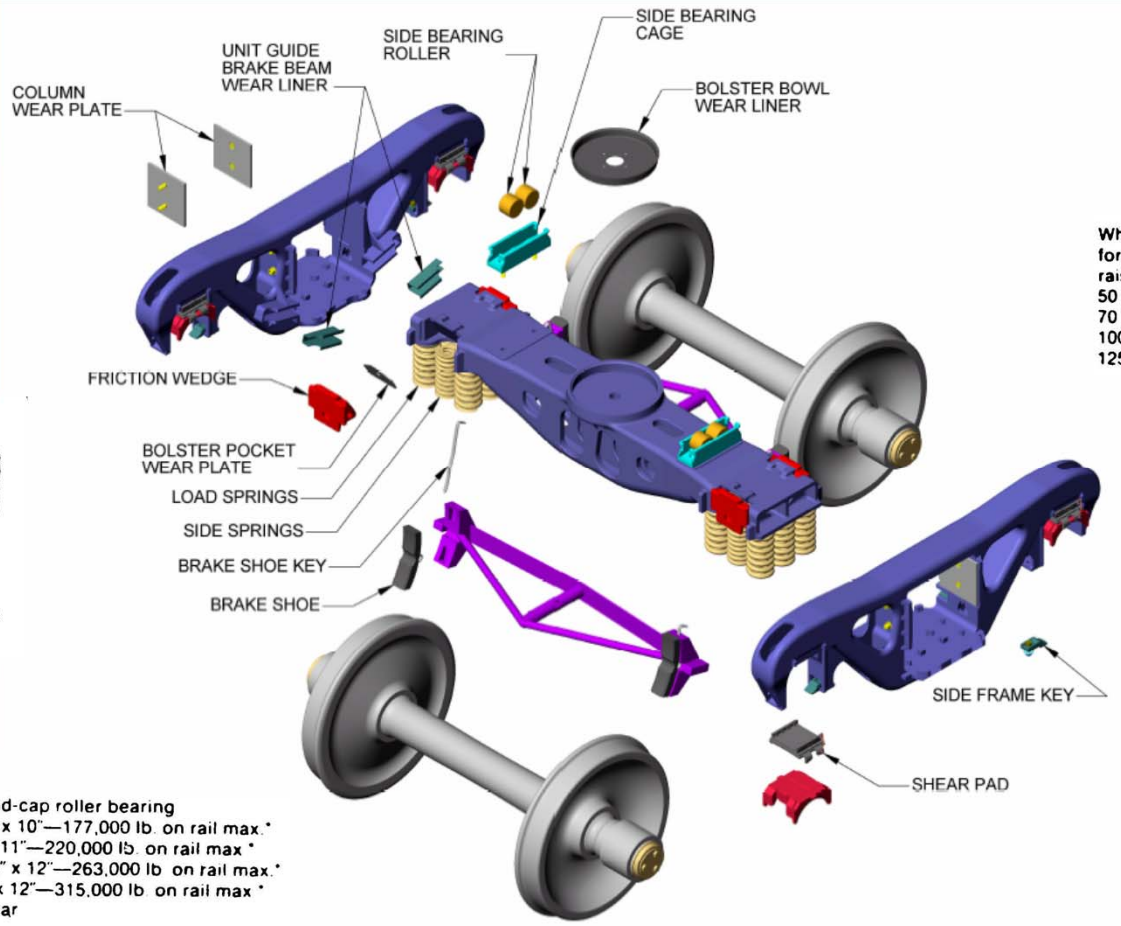
Major Bodies Passenger Vehicles



The Standard 3-Piece Truck:
A long history of design improvements




WHEEL
BOLSTER
SIDE FRAME
ROLLER BEARING
BRAKE BEAM
AXLE
BEARING ADAPTER



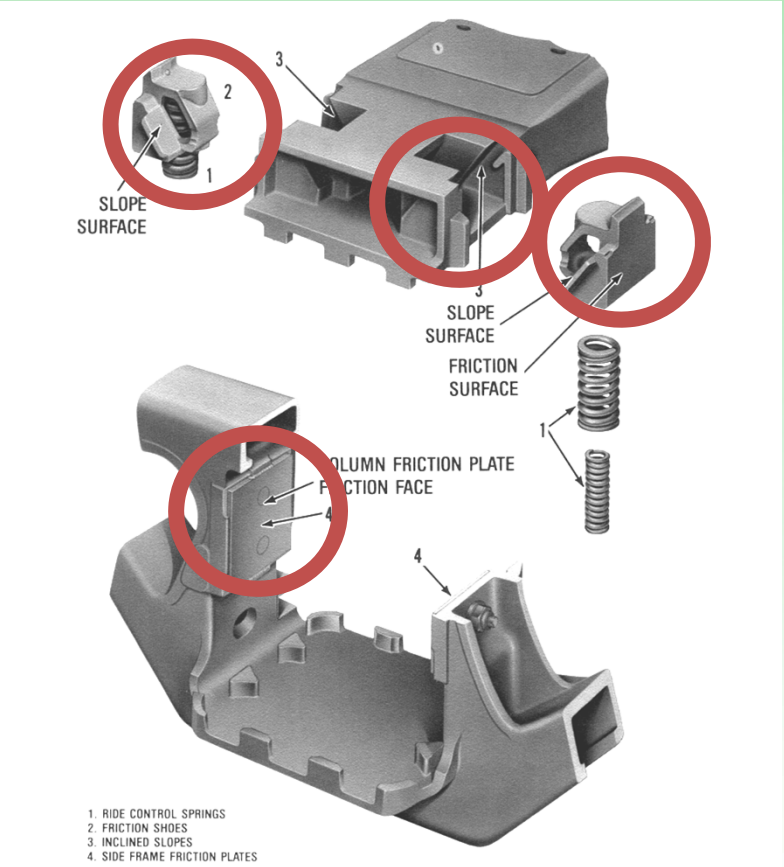
Wheels force-fit on raised-seat axle
50 ton: 33"
70 ton: 33"
100 ton: 36"
125 ton: 38"

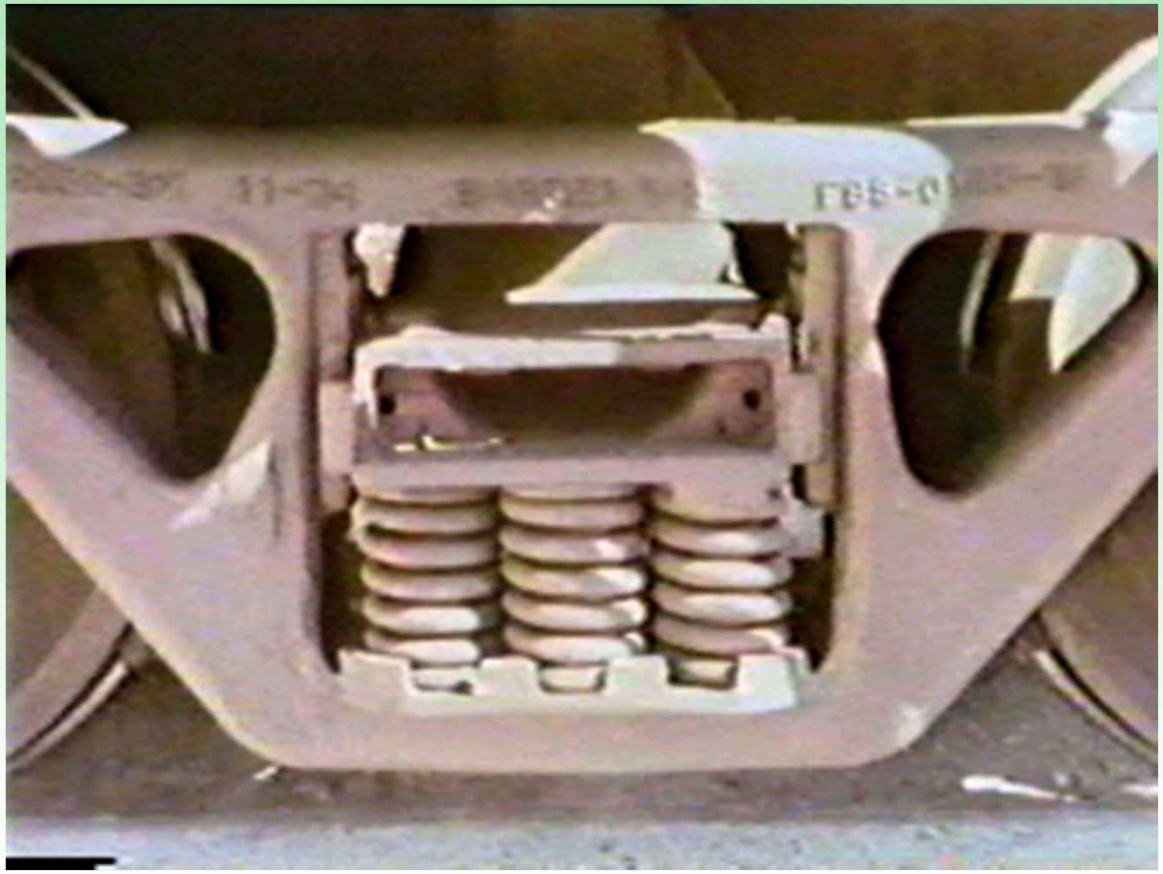
Spring group:
D-3: 2½" travel
D-4: 3 $^{1}/_{16}$" travel
D-5: 3 $^{11}/_{16}$" travel
D-7: 4 $^{1}/_{4}$" travel

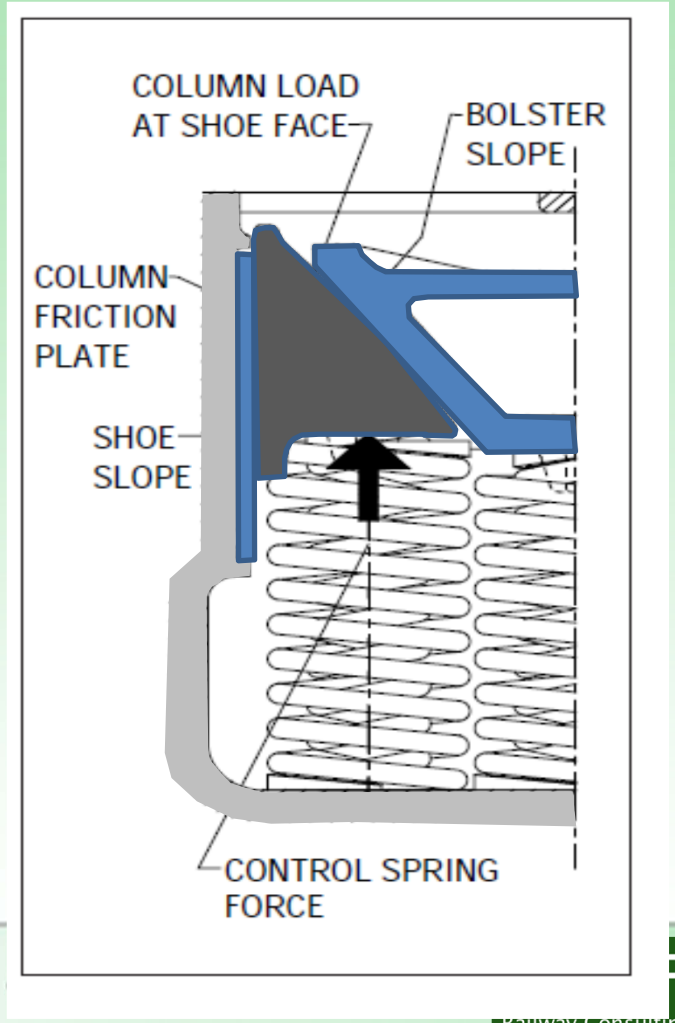
Rotating-end-cap roller bearing
50 ton: 5½" x 10"—177,000 lb. on rail max.*
70 ton: 6" x 11"—220,000 lb. on rail max.*
100 ton: 6½" x 12"—263,000 lb. on rail max.*
125 ton: 7" x 12"—315,000 lb. on rail max.*
*for 4-axle car

Wheelbase:
50 ton: 5' 6"
70 ton: 5' 8"
100 ton: 5' 10"
125 ton: 6' 0"

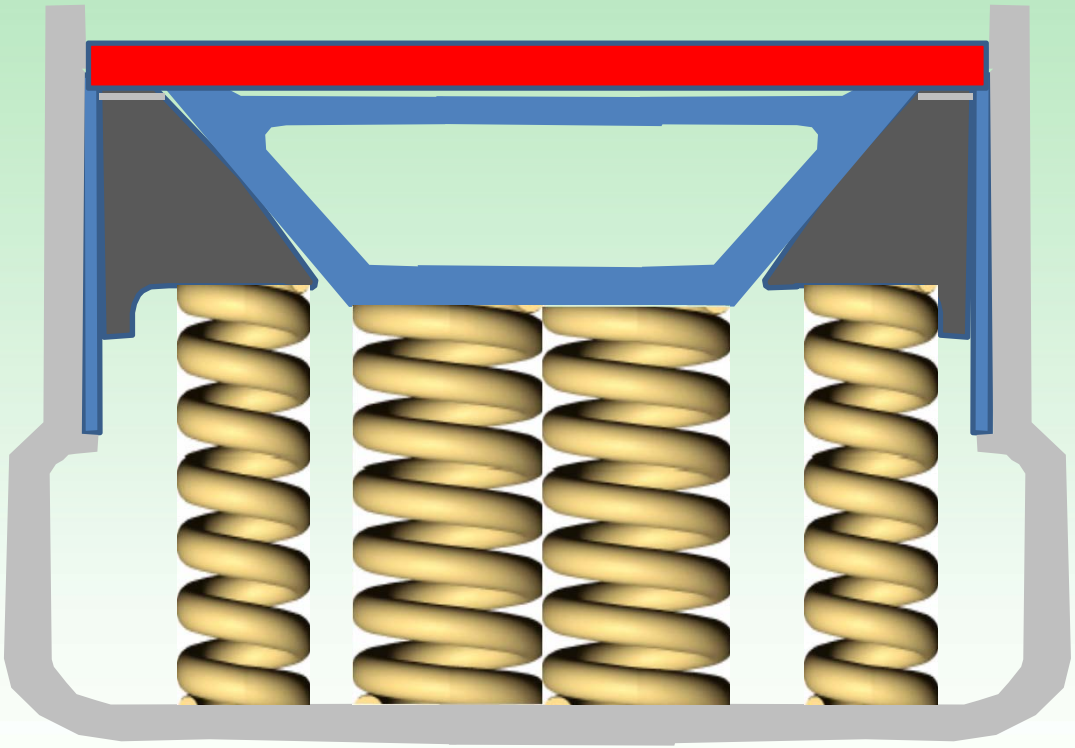
Bolster and Sideframe Interface Area

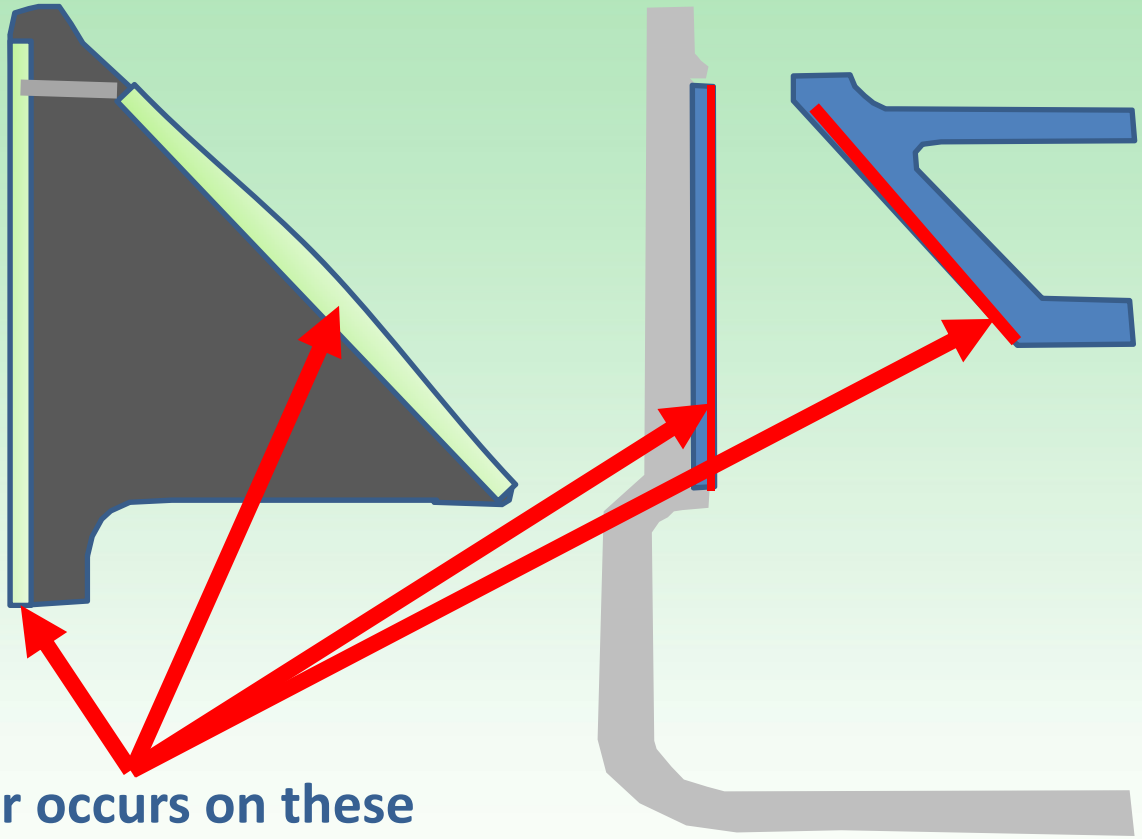





COLUMN LOAD
AT SHOE FACE
BOLSTER
SLOPE
COLUMN
FRICTION
PLATE
SHOE
SLOPE
CONTROL SPRING
FORCE

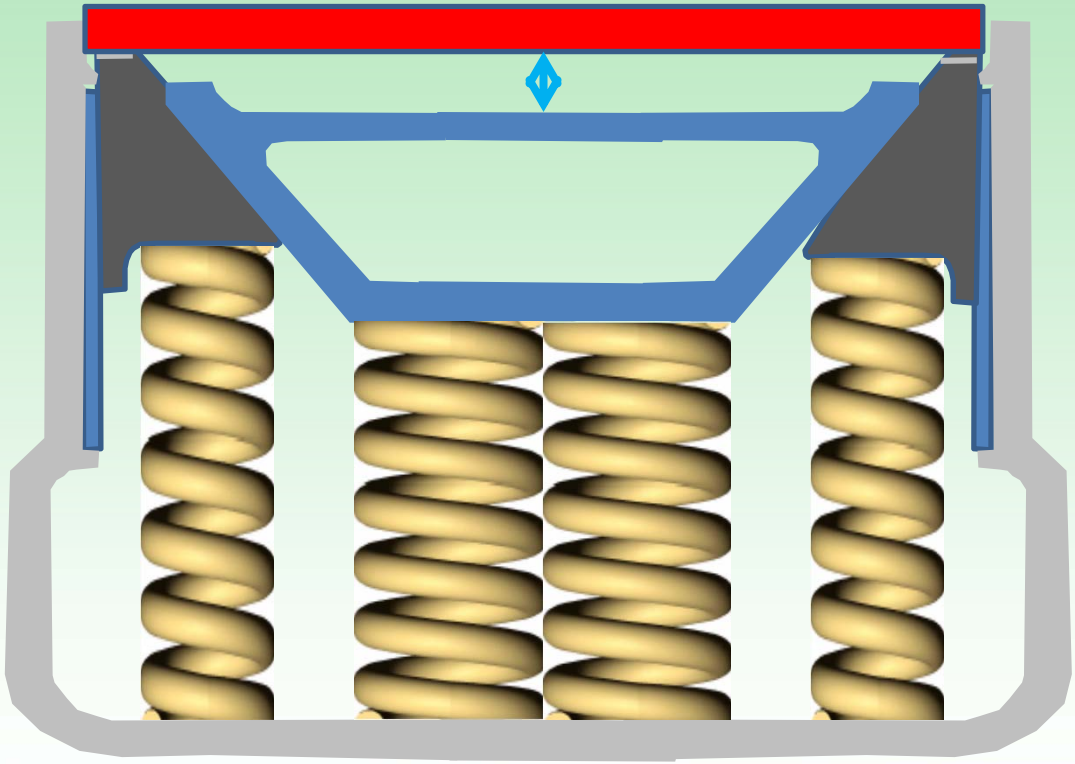
Nominal Wedge Position above top of Bolster





Wear occurs on these 4 surfaces

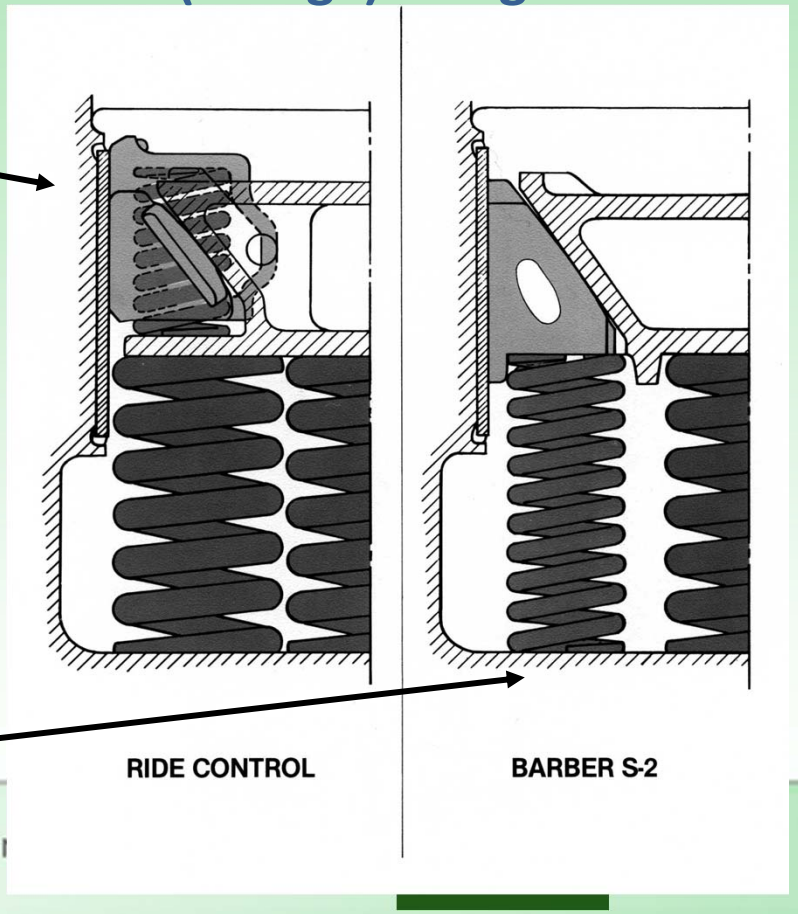
Wedge rise above top of bolster due to wear



AAR Rule 46 (2007)

- Developed to address both friction casting front face wear, and total friction casting rise above top of bolster. Rules applicable when:
  - At any time of inspection
  - When car is on repair track
- Rule 46 also addresses gib wear, centerbowl clearance, and column plate wear

Common Friction Casting (Wedge) Designs

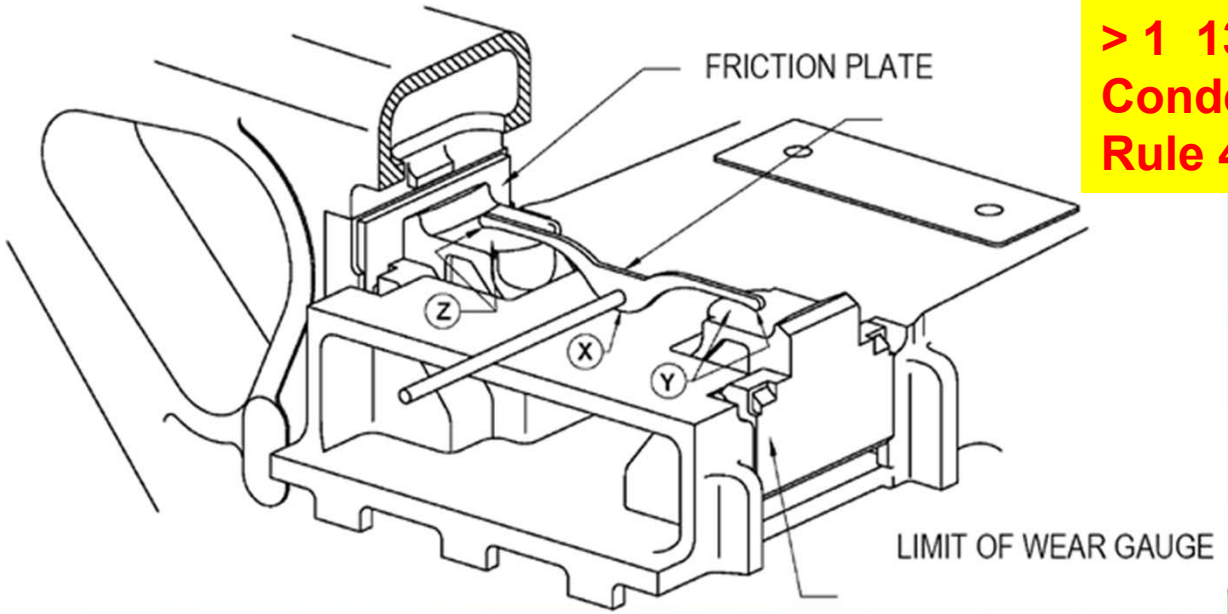


Worn Out Friction Castings (Wedges)

Ride Control Design

AAR Rule 46 - Truck System Performance
A. Wear Limits, Gaging, Cause for Renewal
2. Condemnable When Car is on Repair Track for Any Reason

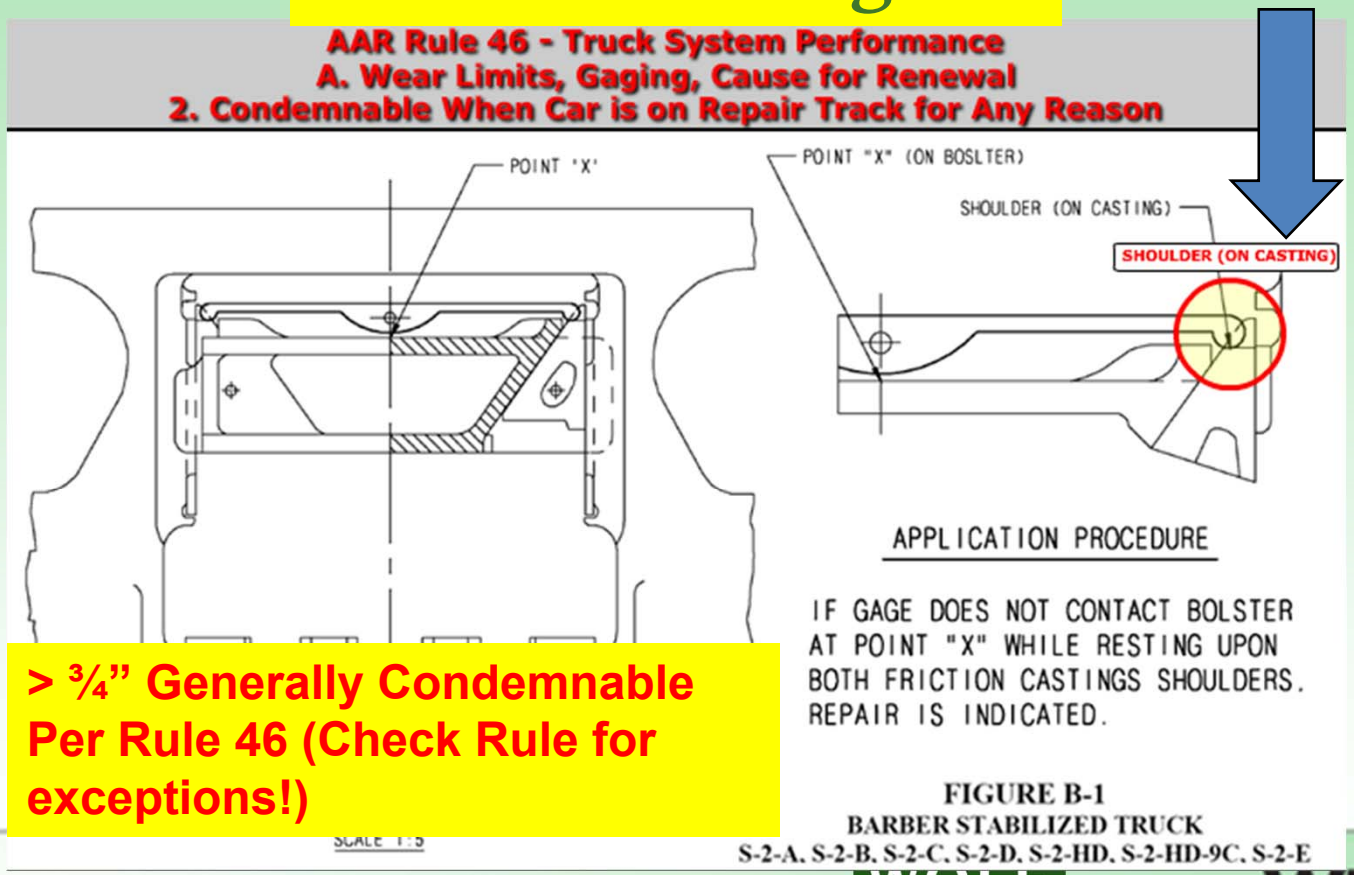
FIGURE A-1
RIDE CONTROL AND SUPER SERVICE RIDE CONTROL TRUCK



> 1 13/16" (~1 ¾") Condemnable Per Rule 46

Barber Design

AAR Rule 46 - Truck System Performance
A. Wear Limits, Gaging, Cause for Renewal
2. Condemnable When Car is on Repair Track for Any Reason



> ¾" Generally Condemnable Per Rule 46 (Check Rule for exceptions!)

FIGURE B-1
BARBER STABILIZED TRUCK
S-2-A, S-2-B, S-2-C, S-2-D, S-2-HD, S-2-HD-9C, S-2-E

Barber Variable Damped Trucks - Allowable Wedge Rise AAR Rule 46

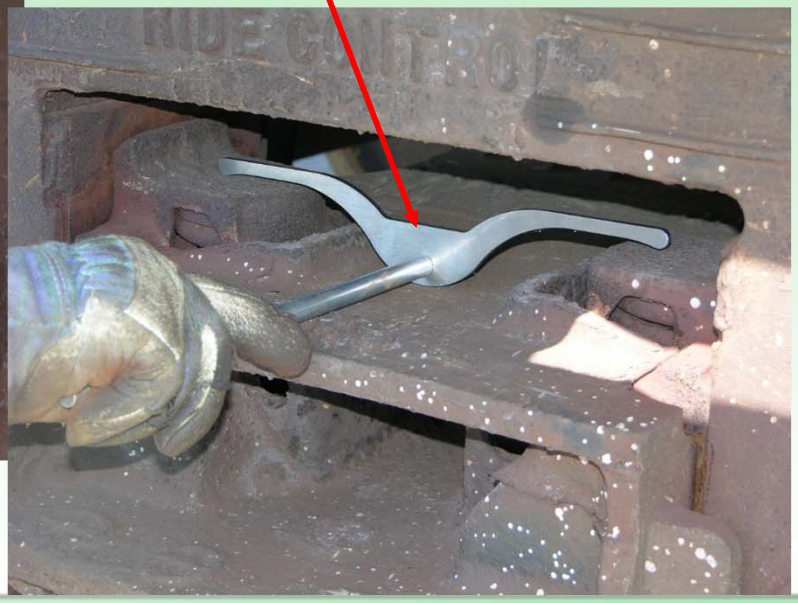
Be Careful!!

Stabilizer Wear Gage Table							
Gage No.	Bearing③ Size	AAR① Spring Travel	Iron Wedge	Split Wedge	Life⑤ Guard Wedge	Twin Guard Wedge	Dim A
SK-1546-1	6 x 11	D-3	609-D	955-SW	913-LG	-	3/4
	6 x 11	D-4 or D-5	678-C 678-B② 787-C 787-B②	925-SW	888-LG	911-PC	
	6 1/2 x 12	D-3	609-D	955-SW	913-LG	-	
	6 1/2 x 12	D-5	876 834-CB 917-C	905-SW 915-SW 945-SW	877-LG 950-LG	921-PC 916-PC	
	6 1/2 x 12	D-7	876	905-SW	877-LG	921-PC	
SK-1546-2	6 1/2 x 12	D-4 or D-5	678-C 678-B② 787-C 787-B②	925-SW	888-LG	911-PC	1/2
SK-1546-3	6 x 11④	D-4	675-C	-	-	922-PC	1 1/4
SK-1546-4	7 x 12	D-5 or D-6	834-CB	915-SW	950-LG	916-PC	1/2
SK-1546-5	7 x 12	D-3 or D-4	762-C	-	-	-	1/4
SK-1546-6	7 x 12	D-5	762-C	-	-	-	3/4

787-C Wedge
½" Wedge Rise

Barber Gage

Ride Control Gage

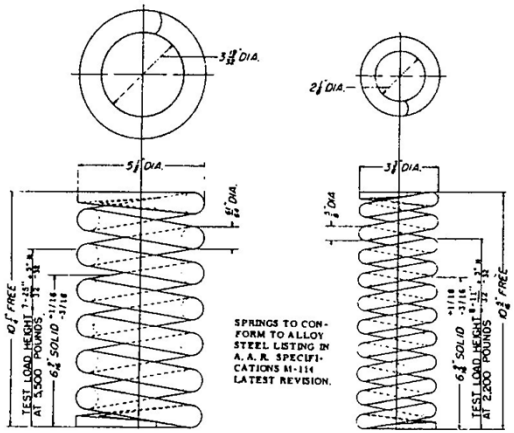


Springs

Association of American Railroads
Mechanical Division
Manual of Standards and Recommended Practices

FREIGHT CAR D5 TRUCK SPRINGS
TOTAL TRAVEL 3-11/16 INCHES

Standard
S-335-78
Adopted as Alternate Standard 1947, Revised 1968, 1976
Advanced to Standard 1964, Corrected 1965, 1970, 1977
Spring Marking-D5 (Adopted, 1958)

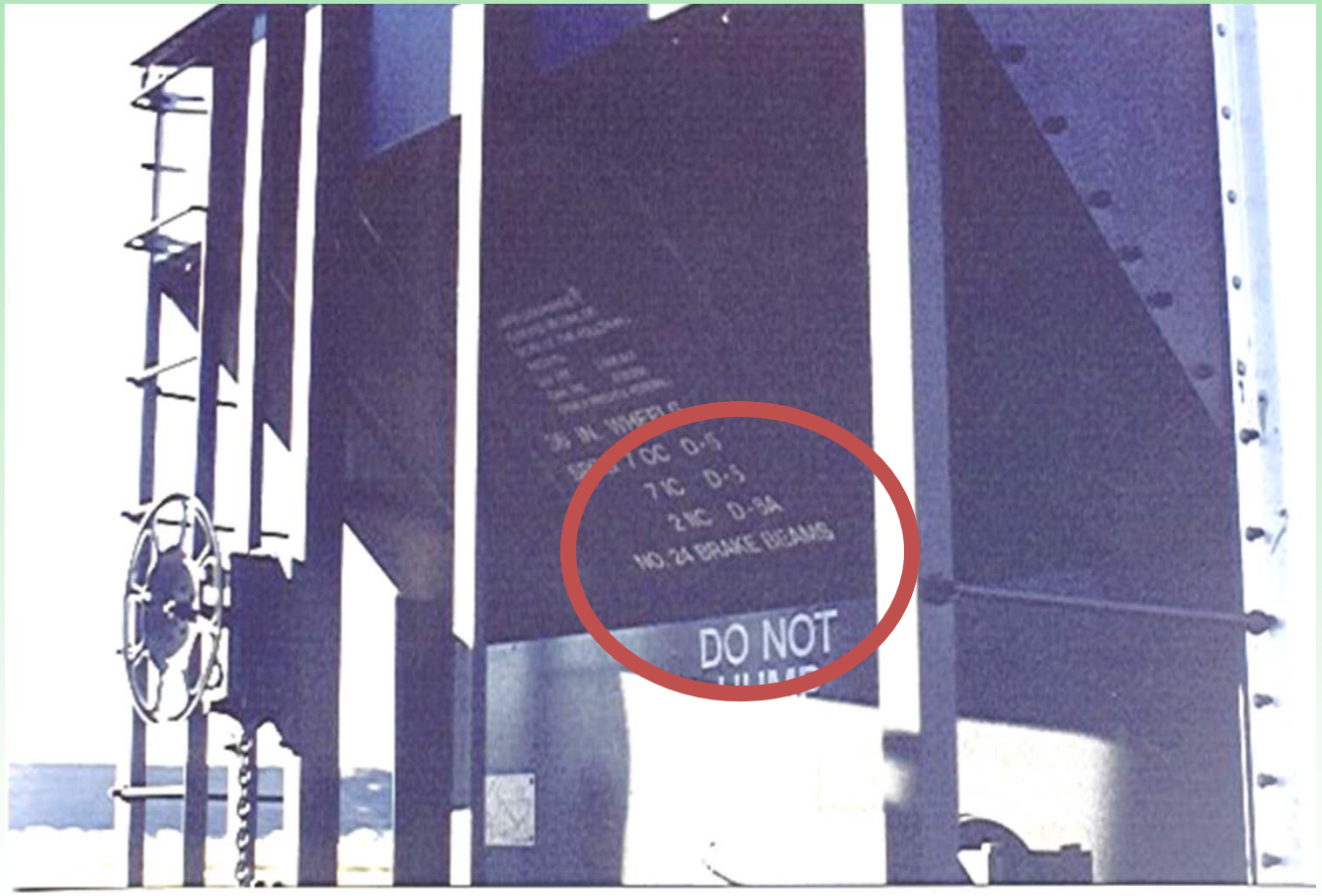


DEFLECTION-FREE TO SOLID = 3 3/16"
SOLID CAPACITY = 8246 LBS.
LEFT HAND WINDING
ENDS TAPERED AND SQUARED
LOAD PER 1/16" DEFLECTION = 140.1 LBS.

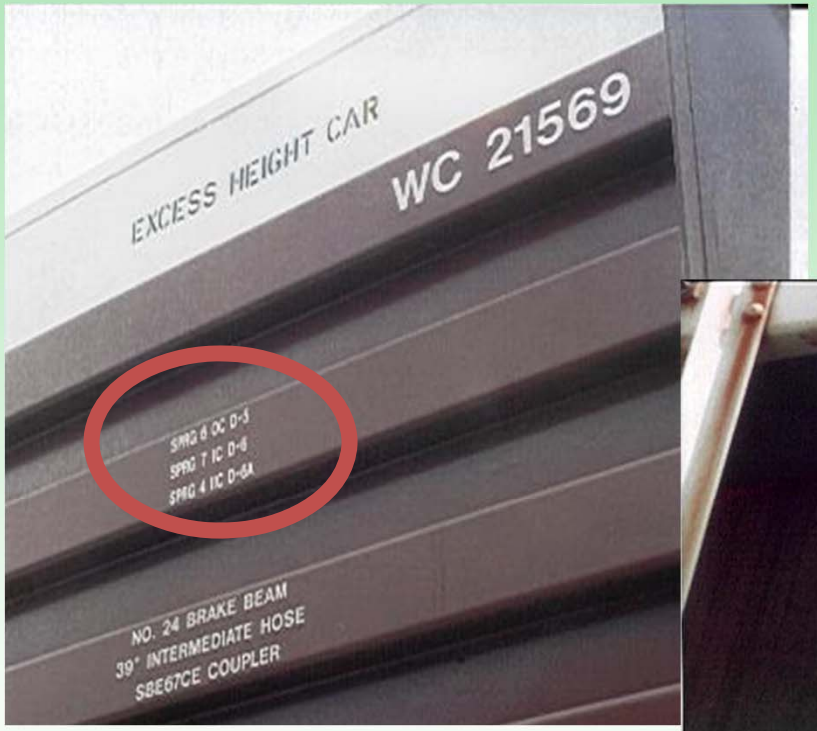
DEFLECTION-FREE TO SOLID = 3 3/16"
SOLID CAPACITY = 4204 LBS.
RIGHT HAND WINDING
ENDS TAPERED AND SQUARED
LOAD PER 1/16" DEFLECTION = 70.1 LBS.

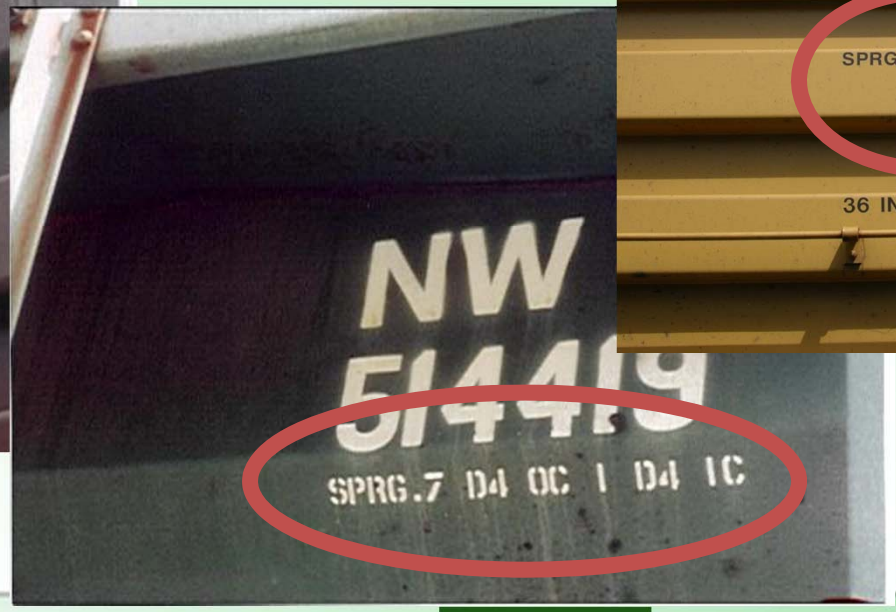
*THE HEIGHT TOLERANCE MAY BE CONVERTED TO A PLUS OR MINUS LOAD TOLERANCE BASED ON THE NOMINAL SPRING RATE.

NOTE — IT IS RECOMMENDED THAT CARS EQUIPPED WITH TRUCKS HAVING THESE LONG TRAVEL SPRINGS BE STENCILED AS FOLLOWS ON EACH END OF CAR WITH FIGURES AND LETTERS 2 INCHES HIGH: SPRG. D5.


7 DC D-5
7 IC D-5
2 IC D-5A
NO. 24 BRAKE BEAMS
DO NOT

Spring Groupings





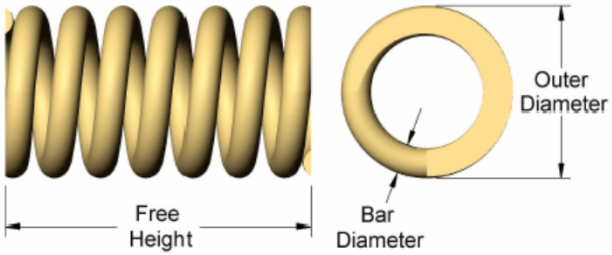
Count Springs; Verify Type; Verify Inner and Outer Springs; Check Free Height

Spring Groupings II

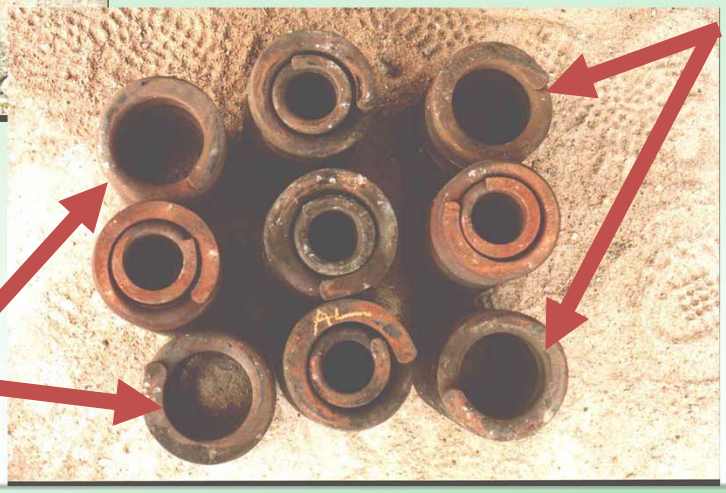
AAR Designated Spring Groups

SINGLE SIDE SPRINGS			
SPRING TRAVEL	2-1/2"	3-1/16"	3-11/16"
FREE HEIGHT	9-1/16"	9-5/8"	10-1/4" (OUTER COIL)
SOLID HEIGHT	6-9/16"	6-9/16"	6-9/16"
5" X 9" JOURNALS	 4-OUTERS D-3 2-INNERS D-5 2-SIDE B-321	 5-OUTERS D-4 1-INNER D-4 2-SIDE B-331	 5-OUTERS D-5 2-INNERS D-5 2-SIDE B-331
WEIGHT PER CAR SET 4-GROUPS (LBS.)	402	431	452
SOLID CAPACITY (LBS)	57066	54525	55190
5-1/2" X 10" JOURNALS	 5-OUTERS D-3 2-INNERS D-3 2-SIDE B-321	 5-OUTERS D-4 5-INNERS D-4 2-SIDE B-331	 5-OUTERS D-5 5-INNERS D-5 2-SIDE B-331
WEIGHT PER CAR SET 4-GROUPS (LBS.)	487	555	545
SOLID CAPACITY (LBS)	67787	68257	67802
6" X 11" JOURNALS	 5-OUTERS D-3 5-INNERS D-3 2-SIDE B-421	 7-OUTERS D-4 3-INNERS D-4 2-SIDE B-432	 7-OUTERS D-5 4-INNERS D-5 2-SIDE B-432
WEIGHT PER CAR SET 4-GROUPS (LBS.)	580	653	670
SOLID CAPACITY (LBS)	84522	83477	83960
6-1/2" X 12" JOURNALS	 7-OUTERS D-3 5-INNERS D-3 2-SIDE B-421	 7-OUTERS D-4 7-INNERS D-4 2-SIDE B-432	 7-OUTERS D-5 7-INNERS D-5 2-SIDE B-432
WEIGHT PER CAR SET 4-GROUPS (LBS.)	402	431	452
SOLID CAPACITY (LBS)	97366	97209	96572

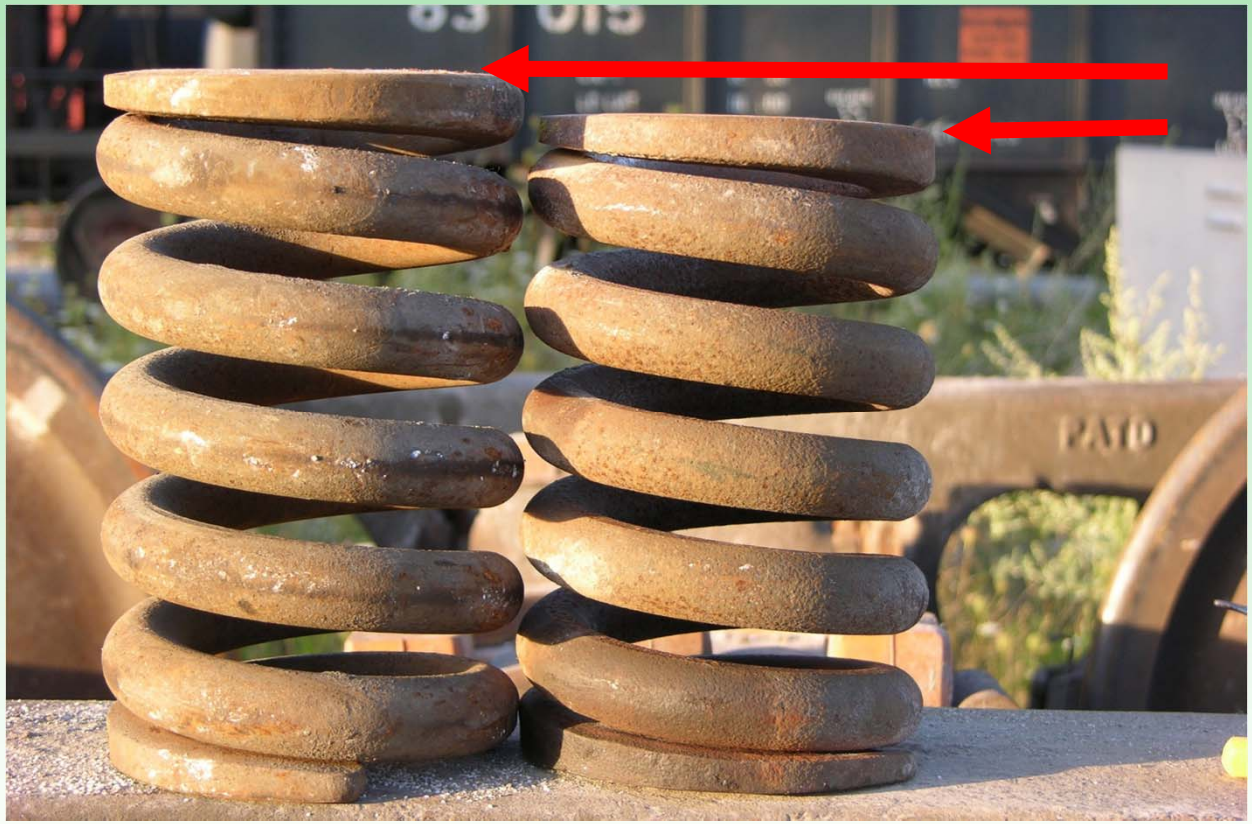
AAR Freight Car						
Part No.	Bar Dia.	Outer Dia.	Solid Height	Free Height	Solid Capacity	Scrap Height
D2-Outer	1 7/32	5 1/2	6 5/8	8 1/4	15,959	7 15/16
D2-Inner	11/16	2 15/16	6 5/8	8 1/4	5,386	7 15/16
D3-Outer	1 1/16	5 1/2	6 9/16	9 1/16	10,721	8 5/8
D3-Inner	21/32	3 1/4	6 9/16	9 1/16	4,299	8 5/8
D4-Outer	1	5 1/2	6 9/16	9 5/8	9,128	9 1/16
D4-Inner	5/8	3 3/8	6 9/16	9 5/8	3,433	9 1/16
D5-Outer	61/64	5 1/2	6 9/16	10 1/4	8,266	9 5/8
D5-Inner	5/8	3 3/8	6 9/16	10 5/16	4,204	9 5/8
D6-Inner	21/32	3 7/16	6 9/16	9 15/16	4,707	9 5/16
D6A-Inner	3/8	2	5 11/16	9	1,536	8 3/8
D7-Outer	15/16	5 1/2	6 9/16	10 13/16	8,642	10
D7-Inner	5/8	3 1/2	6 9/16	10 3/4	4,108	10



Right Side

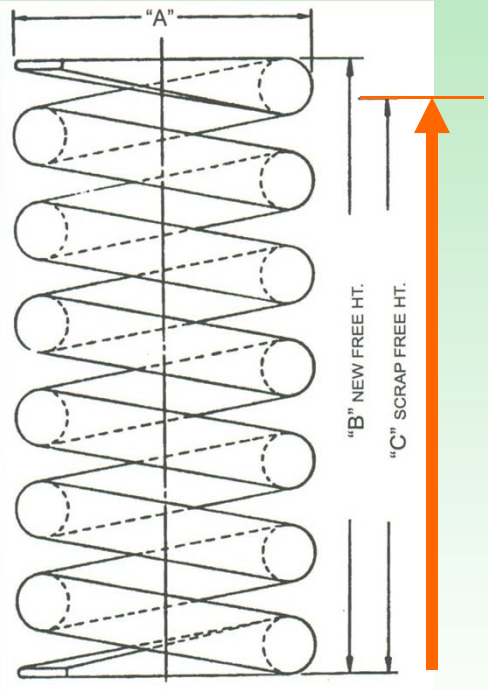


Left Side;
Missing corner inner coils



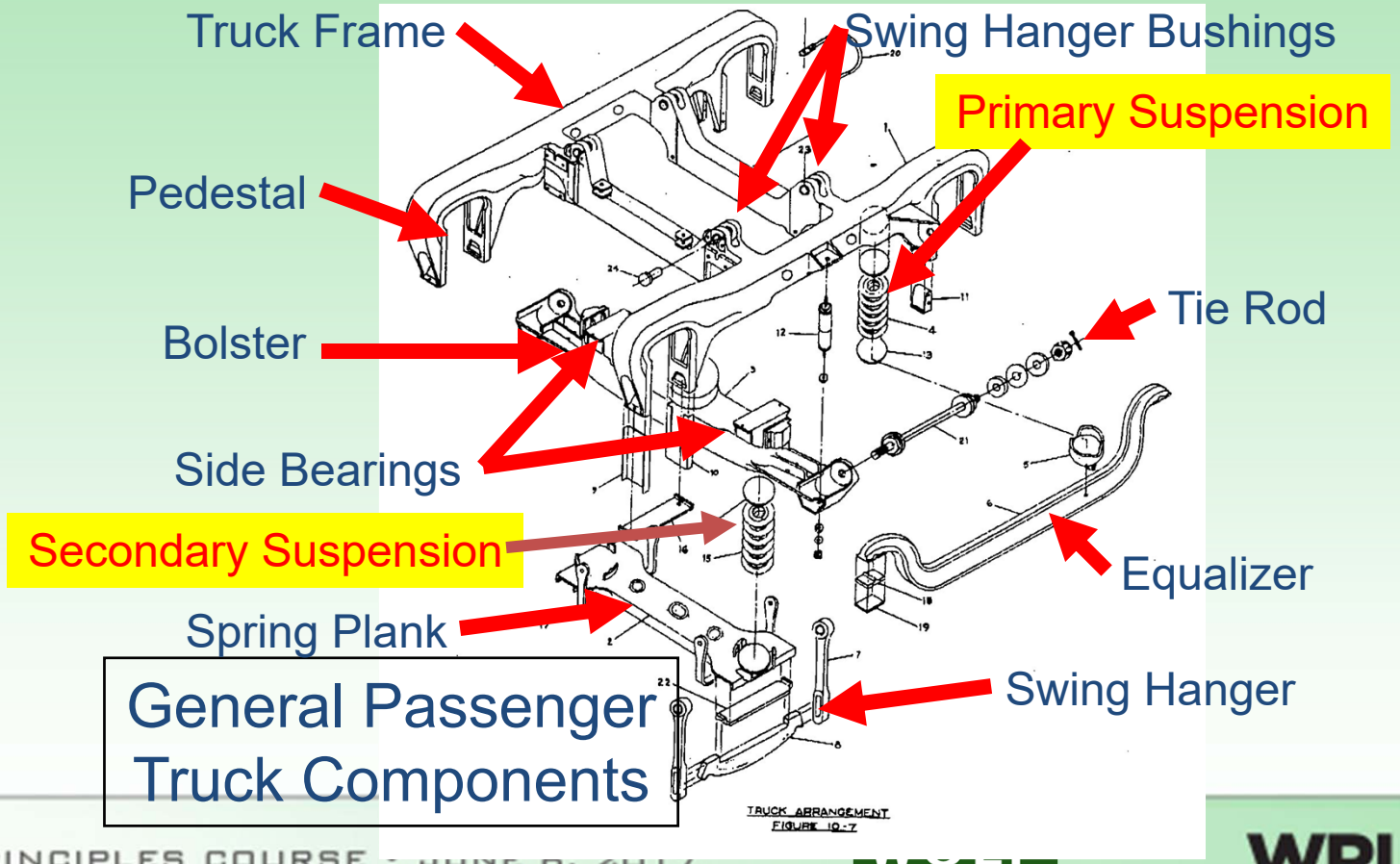
Spring showing sign of fatigue/set

Checking Free Height

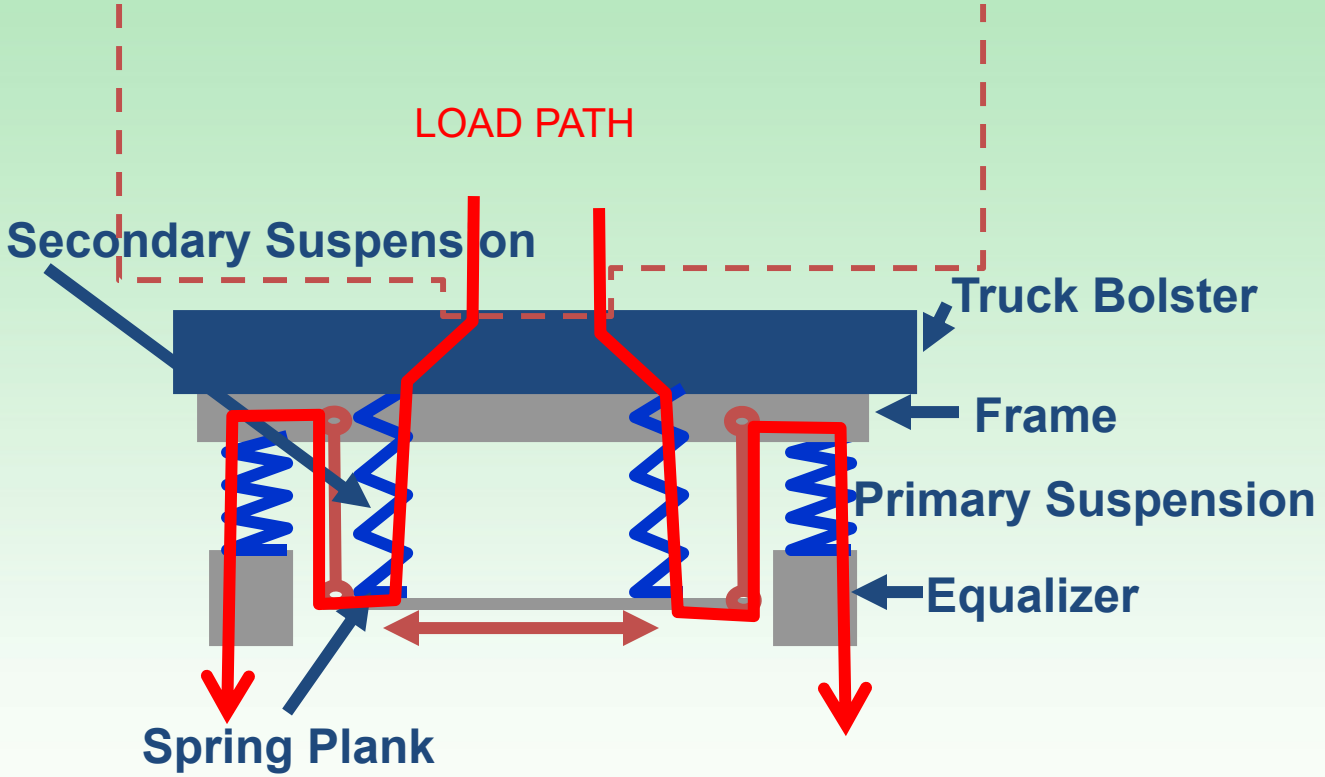


Broken Spring

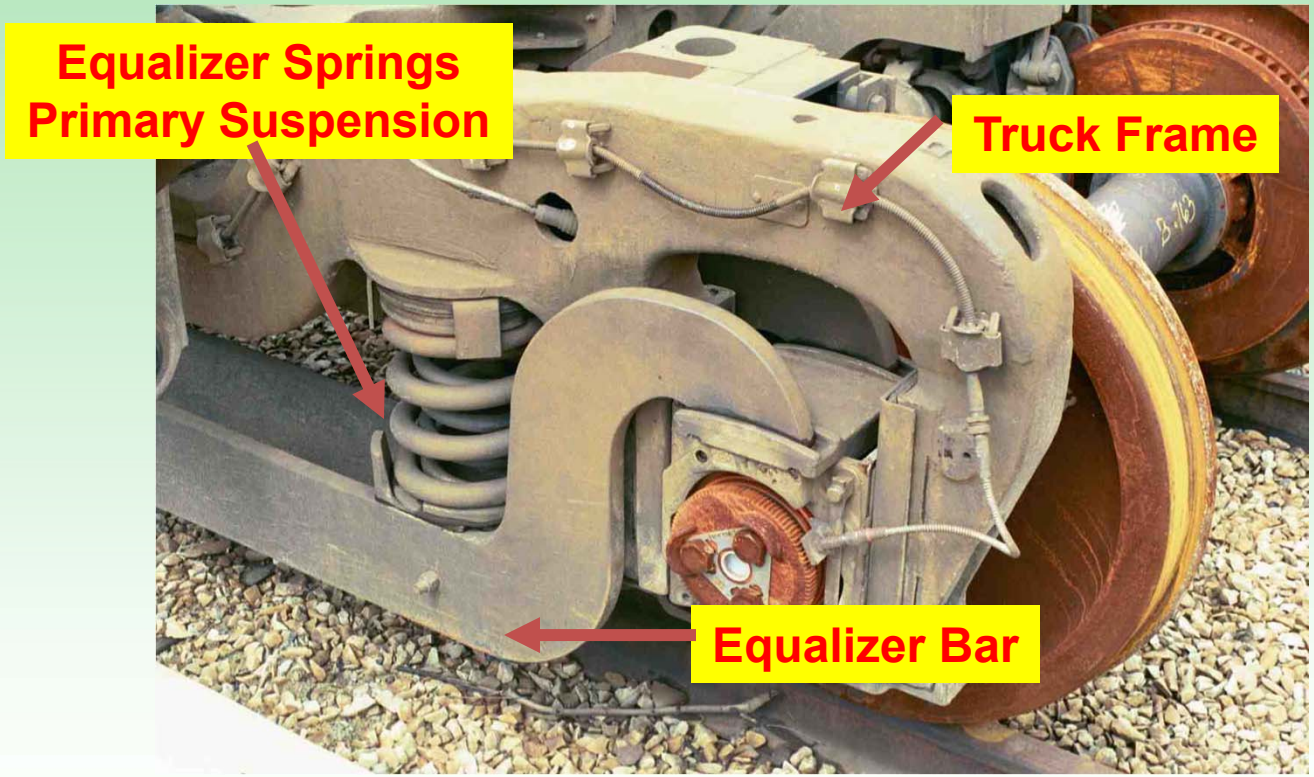
Solid Spring – Indicates Excessive Rock/Roll

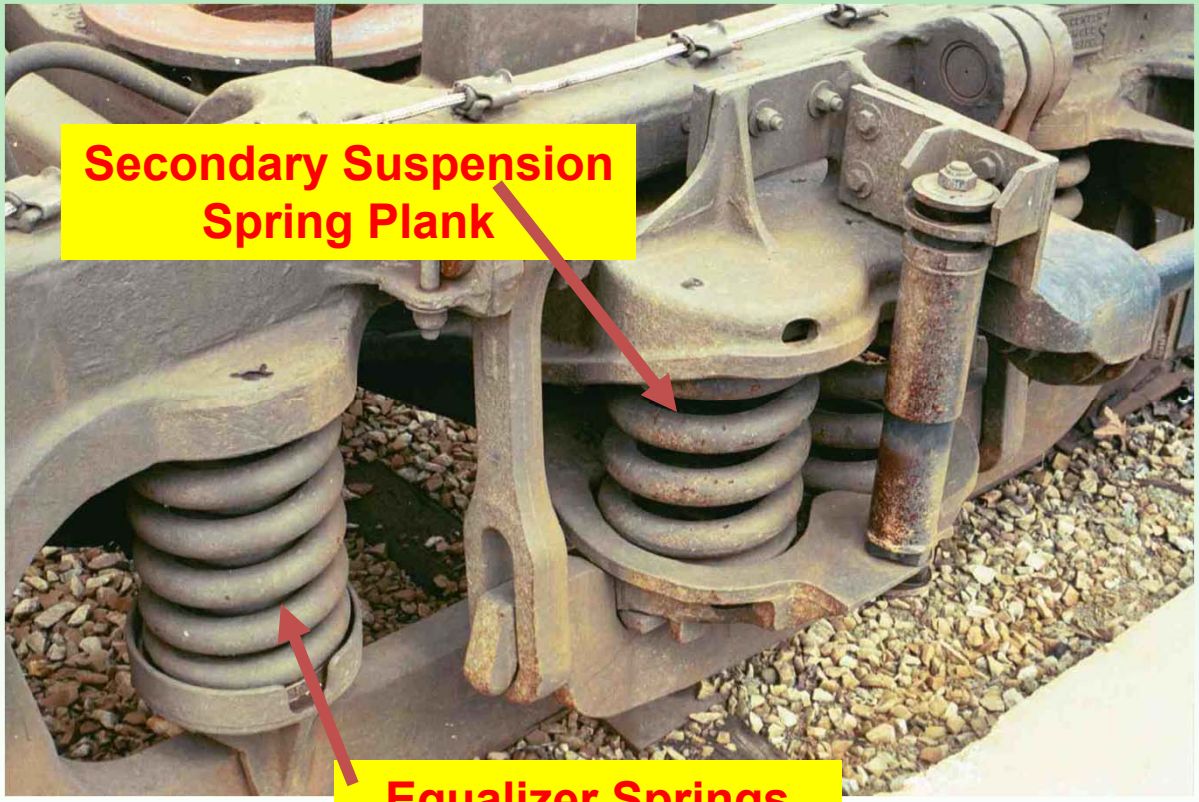


General Passenger Truck Components

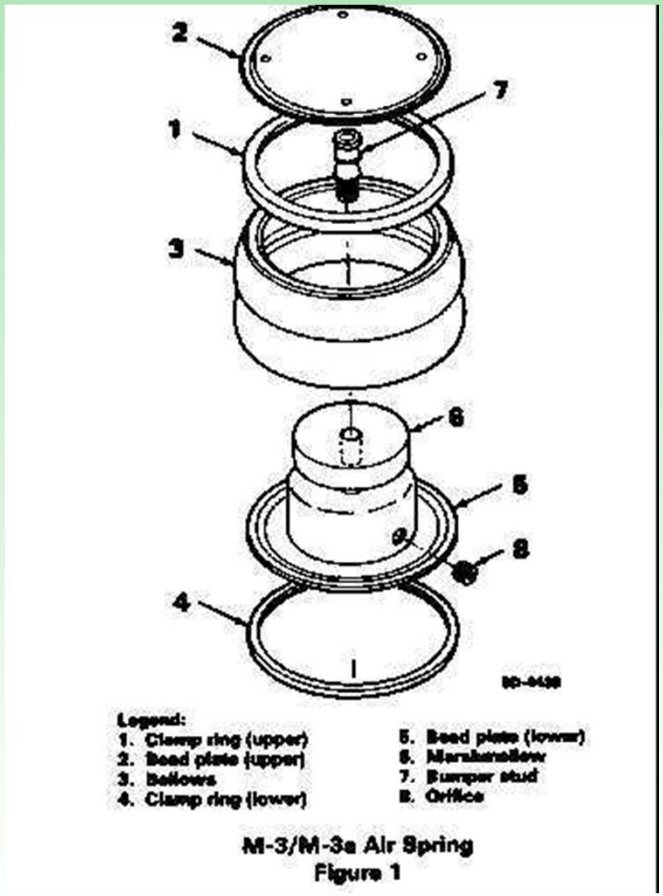


Basic GSI 70 Suspension

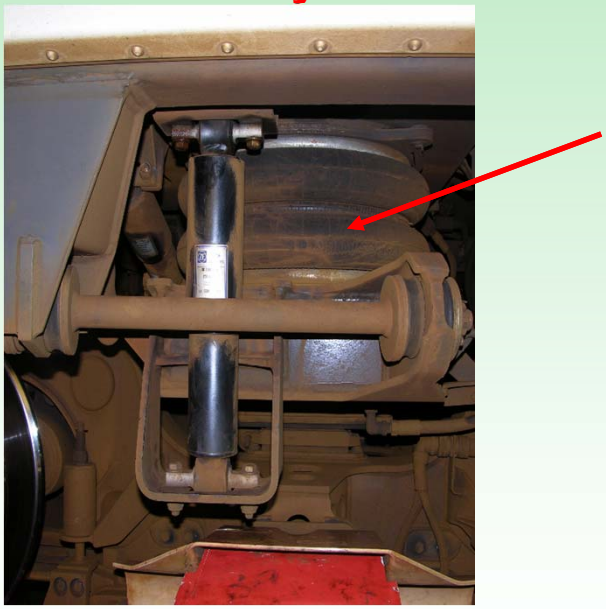

Equalizer Springs
Primary Suspension
Truck Frame
Equalizer Bar


Secondary Suspension
Spring Plank
Equalizer Springs
Primary Suspension

Air Spring Secondary Suspension Between Bolster and Car Body

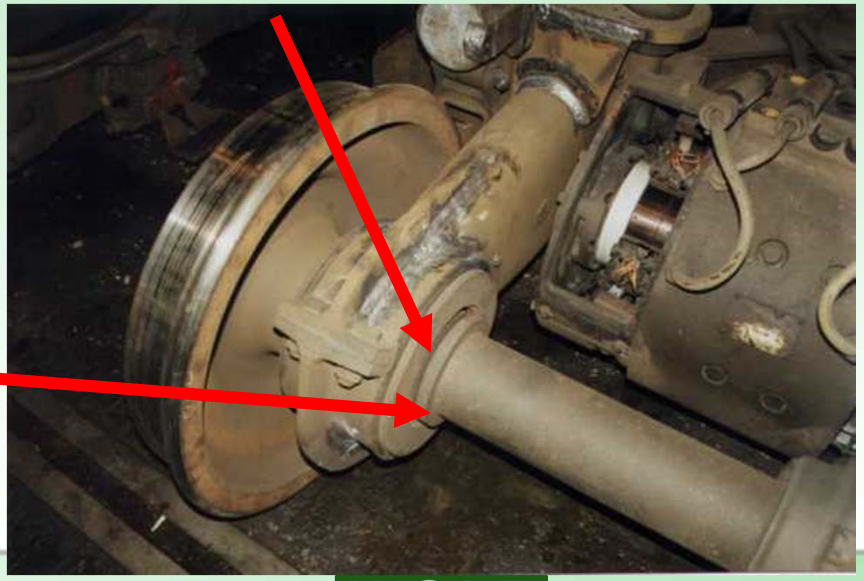


M-3/M-3a Air Spring
Figure 1



Amfleet Passenger Car Trucks

Primary suspension
at each journal



Shock
Ring

Light Rail Vehicle Suspension

Air Spring
Secondary Suspension
Between Bolster and
Frame

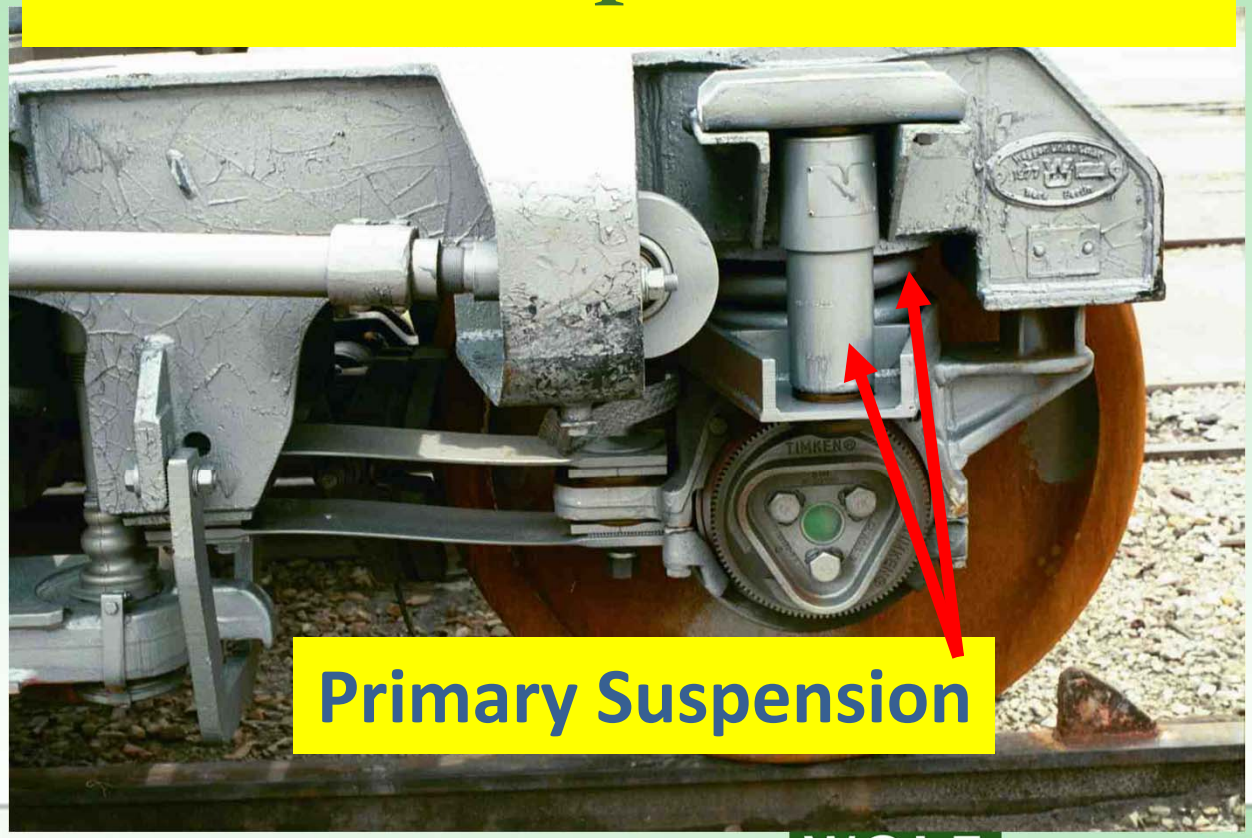
Note: vertical damper

Primary suspension
at each journal

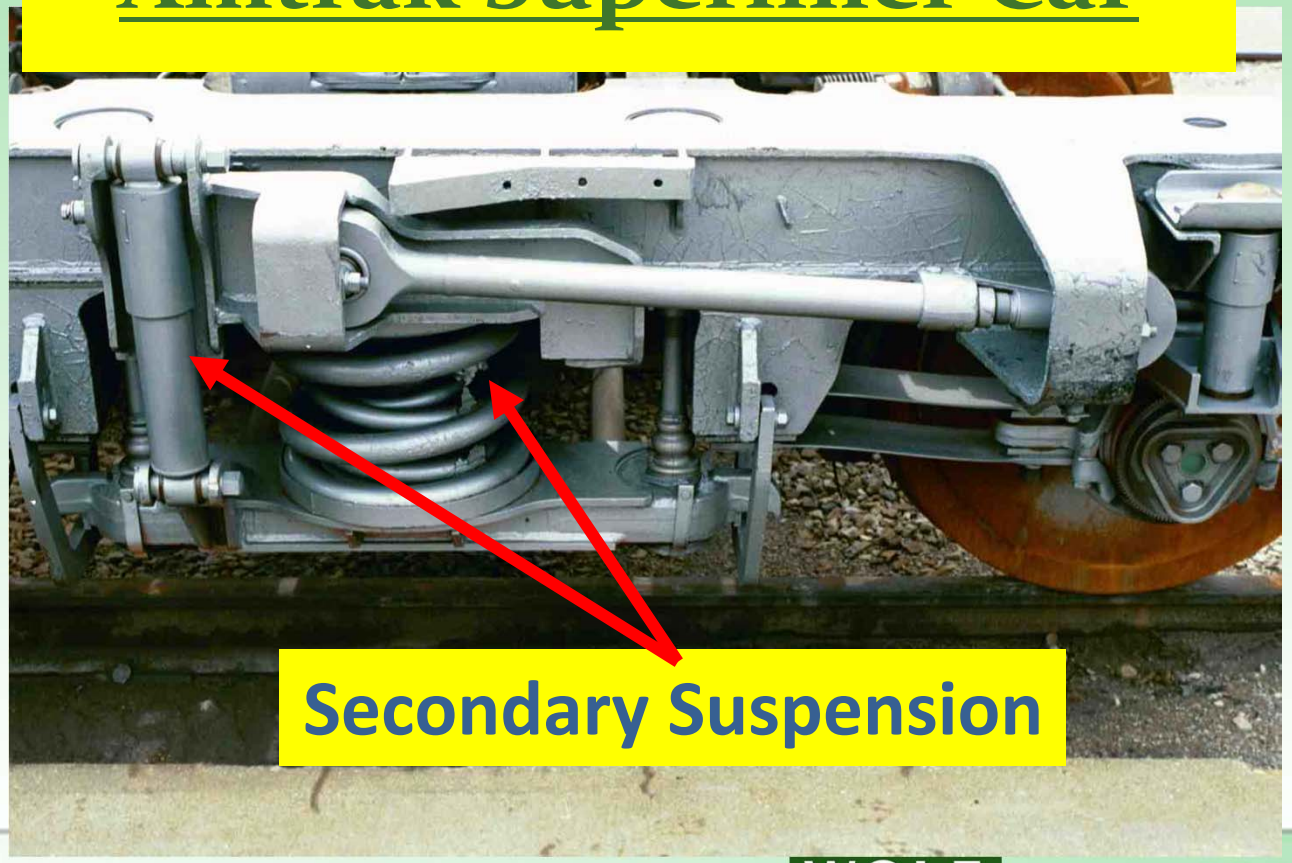
Amtrak Superliner Car

Wagon Union Truck

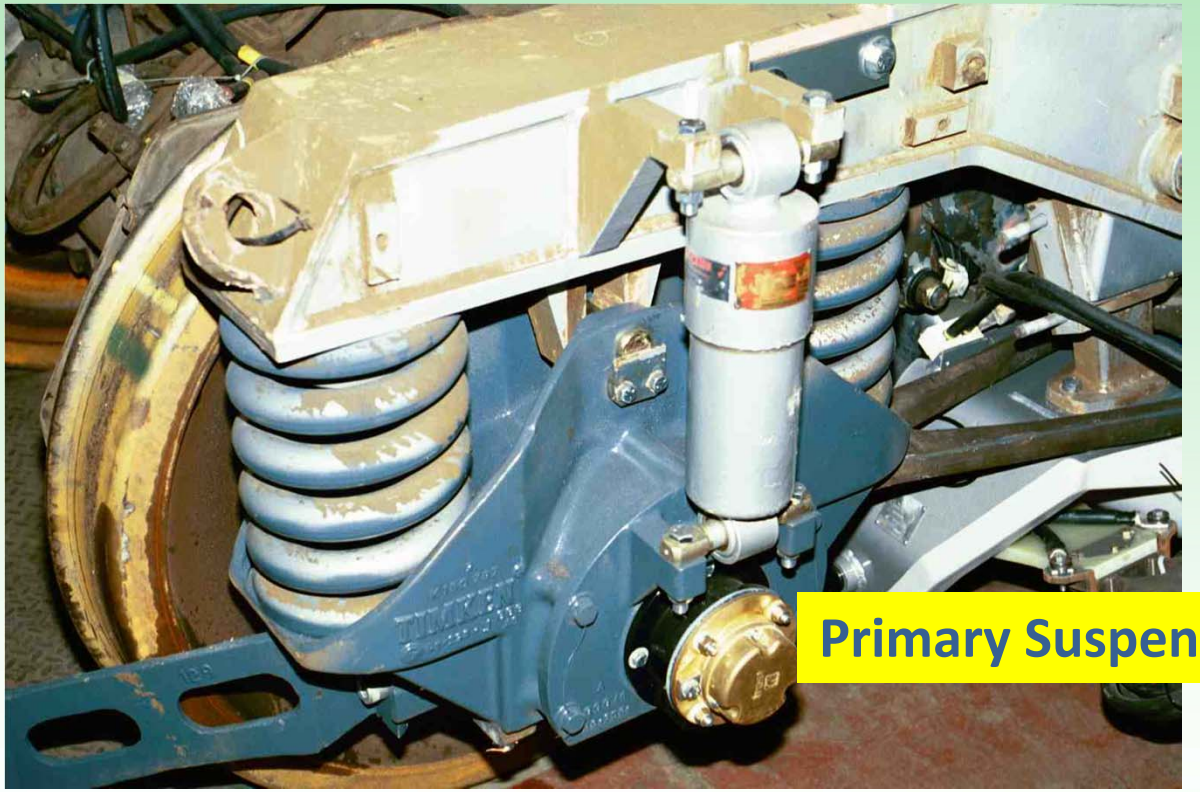
Amtrak Superliner Car



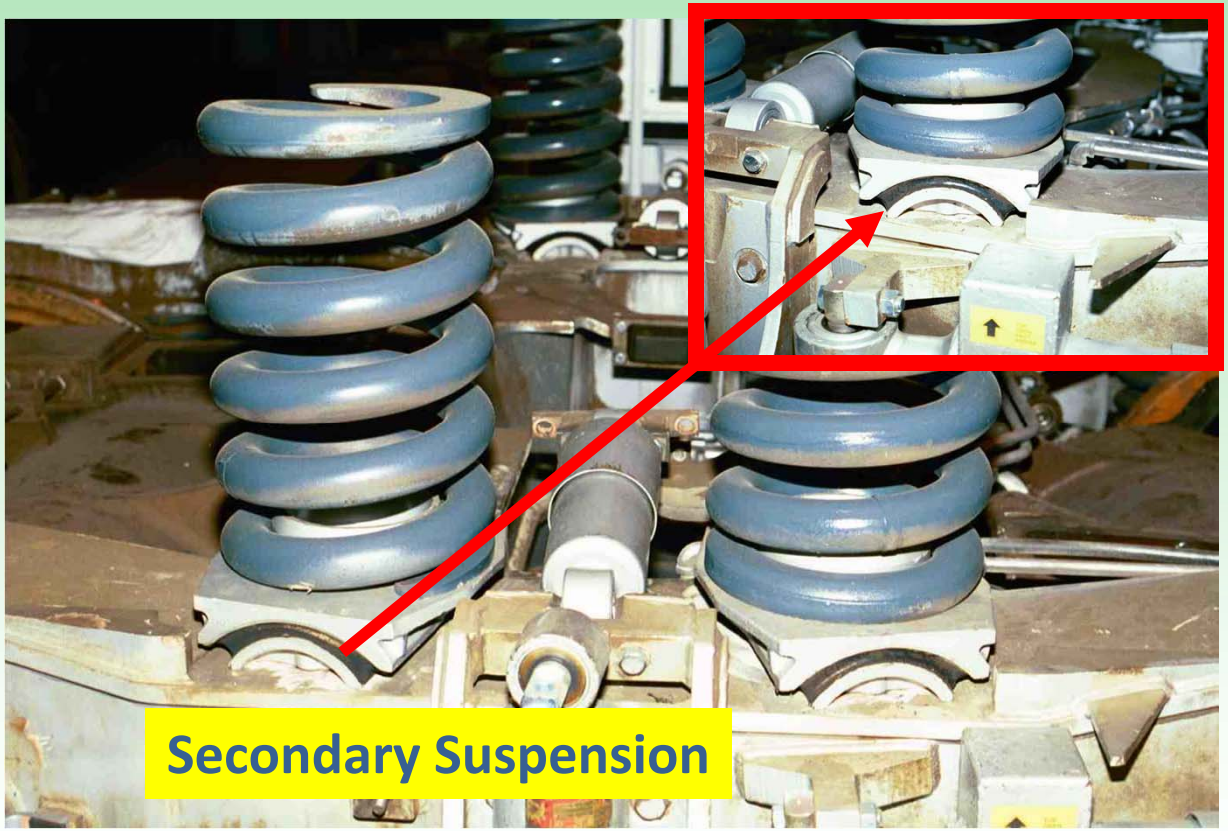
Amtrak Superliner Car



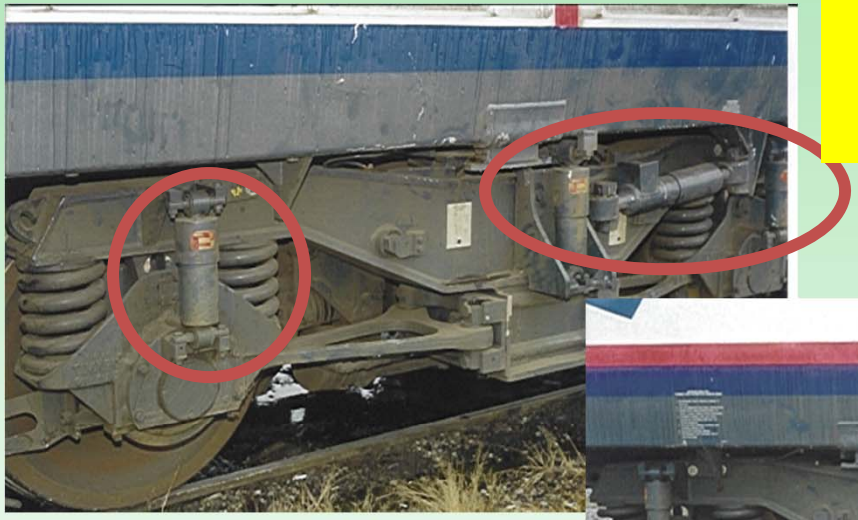
Locomotive Suspensions



Primary Suspension

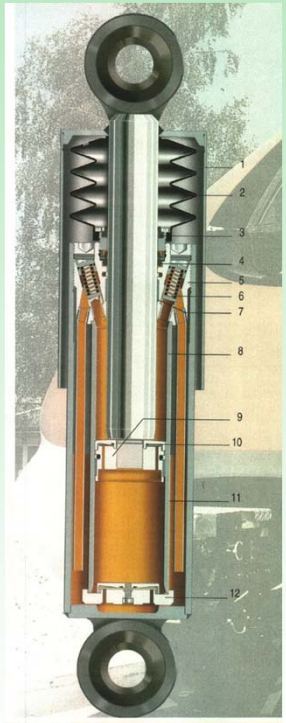

Secondary Suspension

Genesis Trucks



Dampers

- Mostly hydraulic or friction style used on passenger cars
- Used to absorb lateral and vertical shocks from track
- Dissipates Energy from spring suspension
- Restores ride quality



Courtesy Koni Company

Hydraulic Dampers - Construction

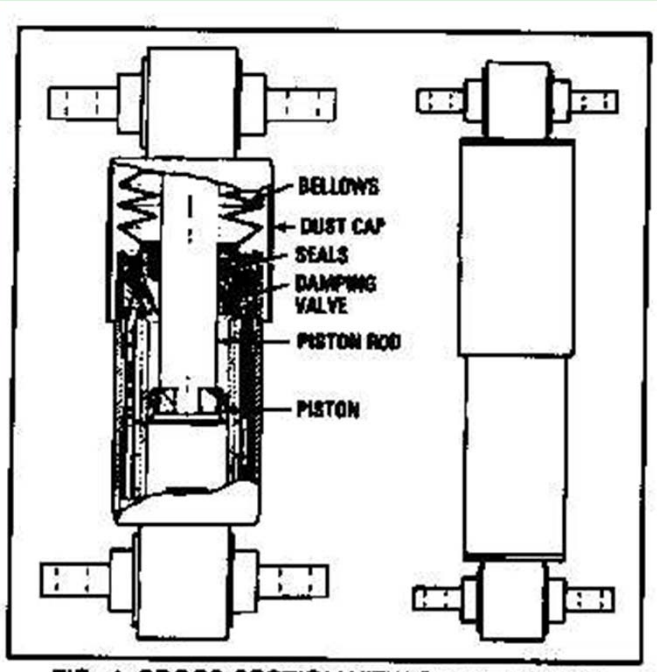
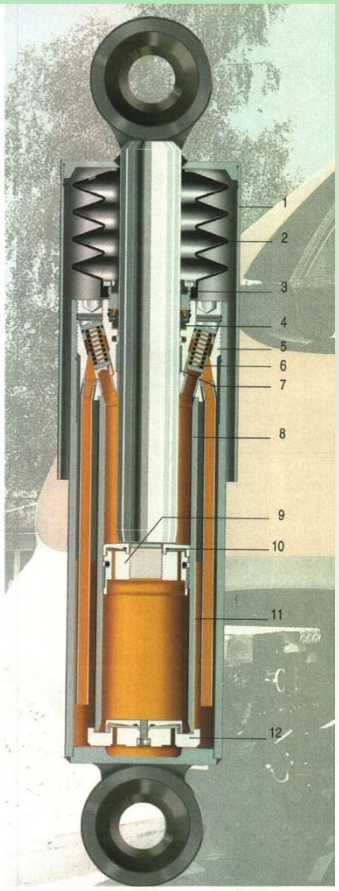
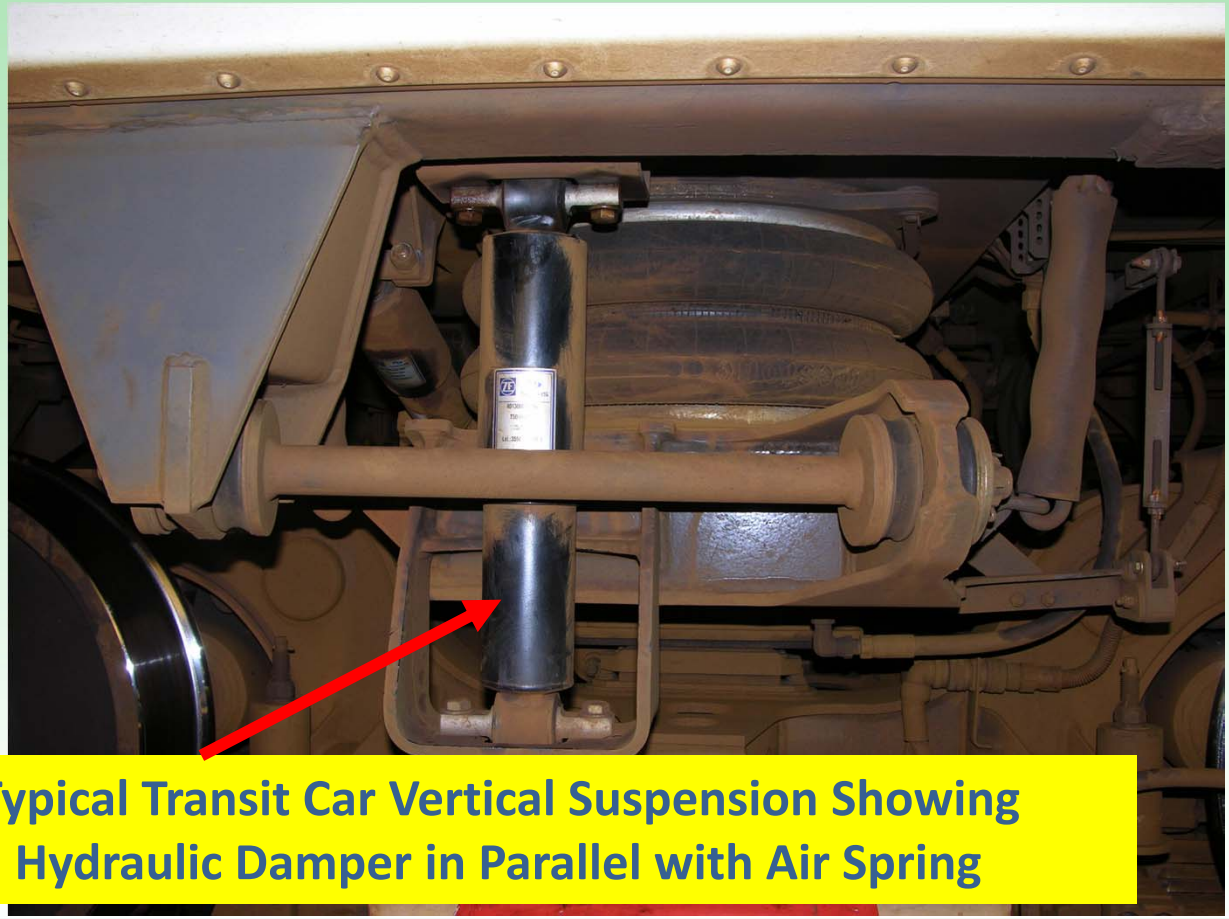


FIG. 4. CROSS SECTION VIEW OF HYDRAULIC SNUBBER (TYPICAL). E-33517.

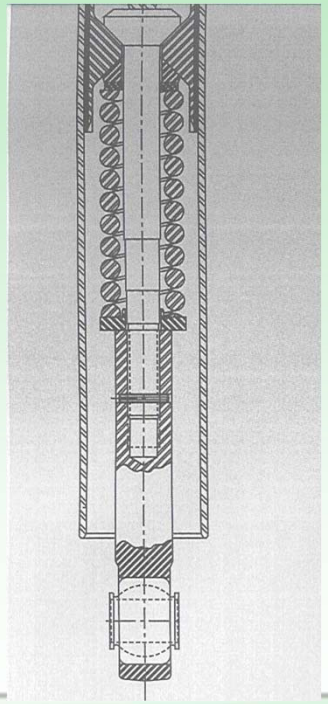


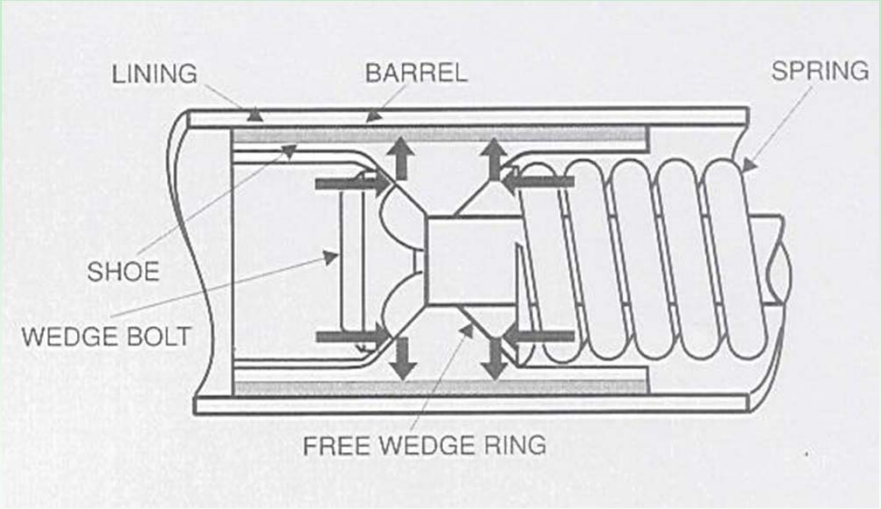
Courtesy Koni Company



Typical Transit Car Vertical Suspension Showing Hydraulic Damper in Parallel with Air Spring

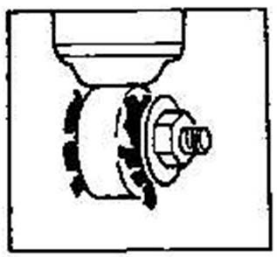
Friction Dampers



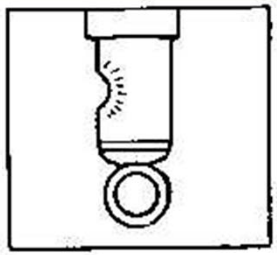


Courtesy Vibratech Company

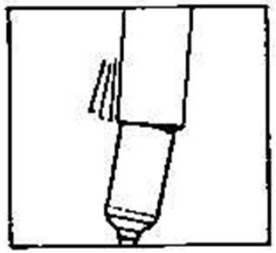
Dampers - Inspection Items



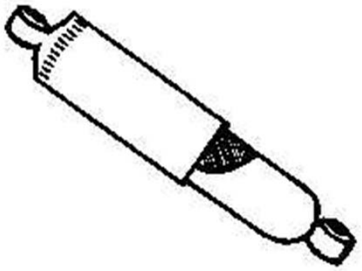
WORN BUSHINGS
Will make shock absorbers noisy and reduce their effectiveness.



BODY DAMAGE
Large dents in the shock absorber will cause the unit to deteriorate.

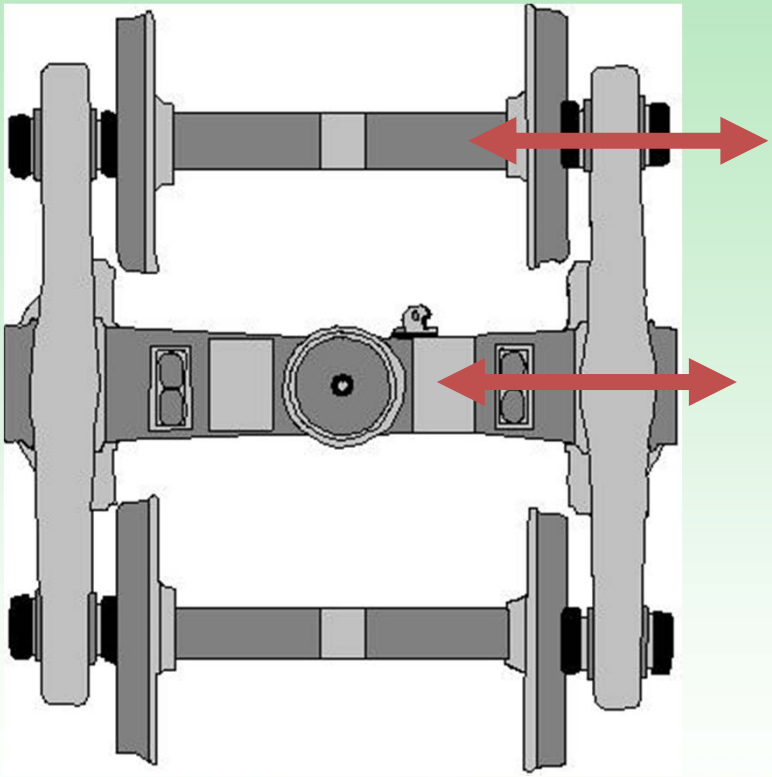


LOOSE DUST SHIELD
Will cause noise and may further damage the unit.



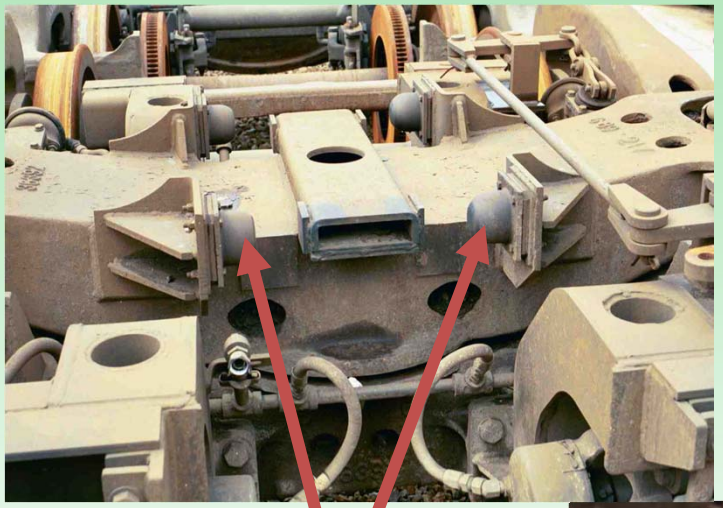
LEAKING FLUID
Will make shock absorber lose effectiveness.

Lateral Suspension



Lateral Suspension

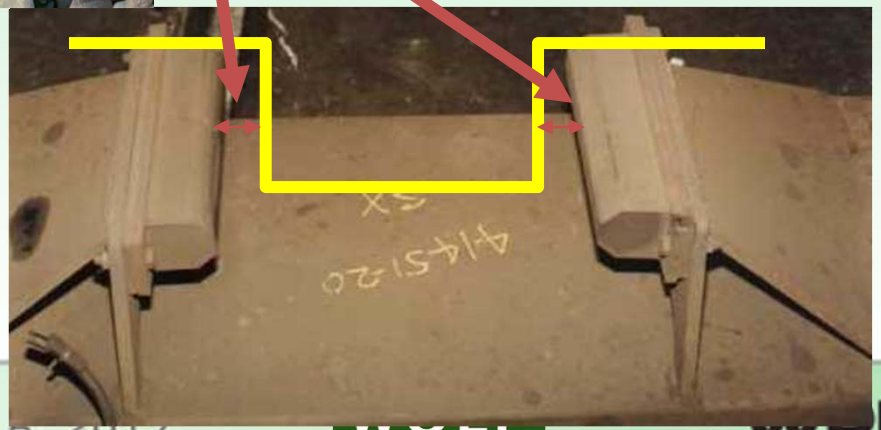
- 3-Piece trucks have relatively poor lateral suspension characteristics, relying primarily on shear stiffness of load springs and friction damping due to wedge motion
- Passenger/locomotive trucks have improved lateral suspension relying on both swing motion of the bolsters, shear of the secondary springs, and bump stops. In addition, lateral shock dampers are used.

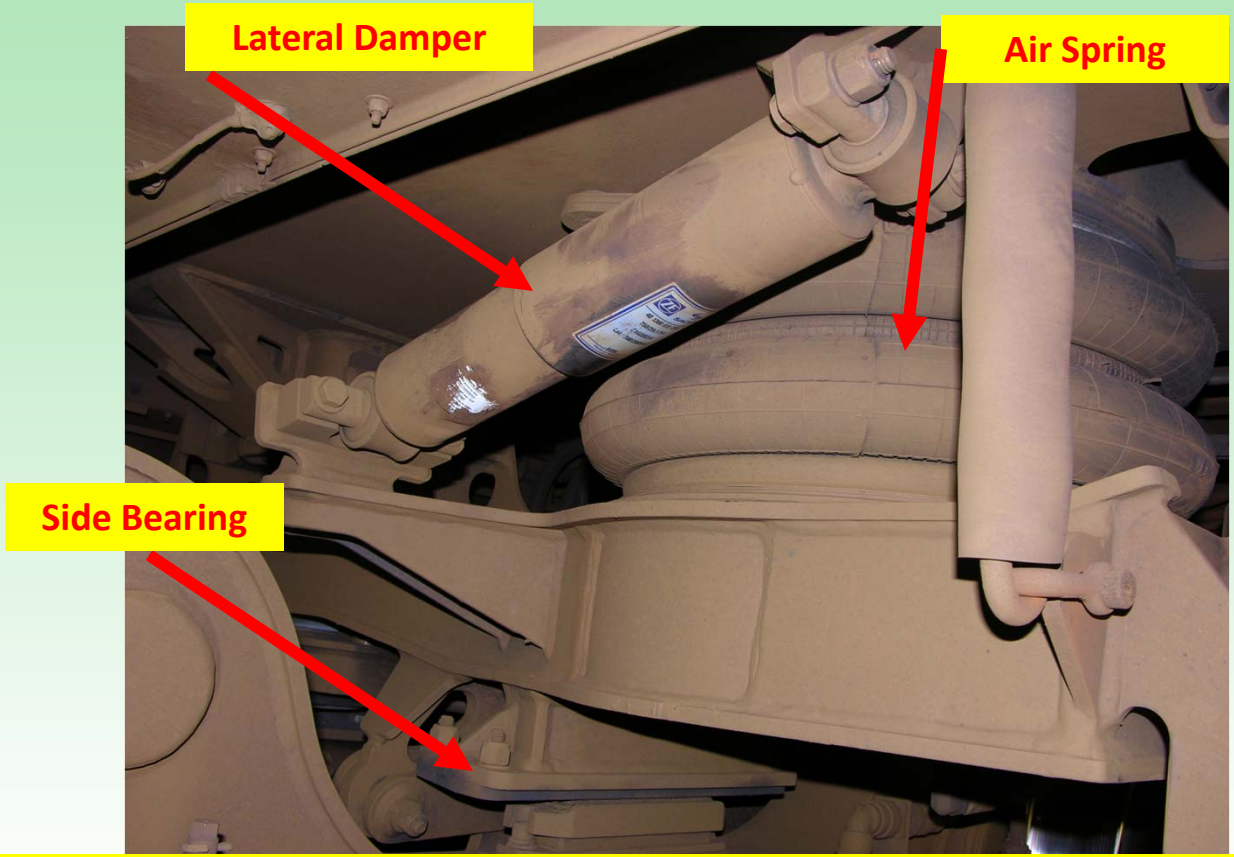


Bolster & Lateral Bump Stops

1” Nominal Bolster Stop to Body clearance; +1/4”, -0” tolerance

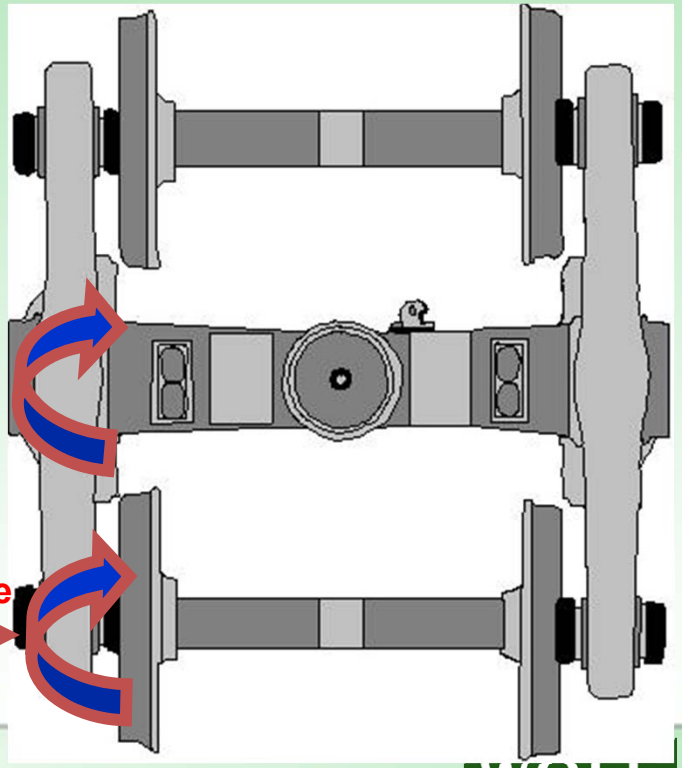
Lateral Bump Stops



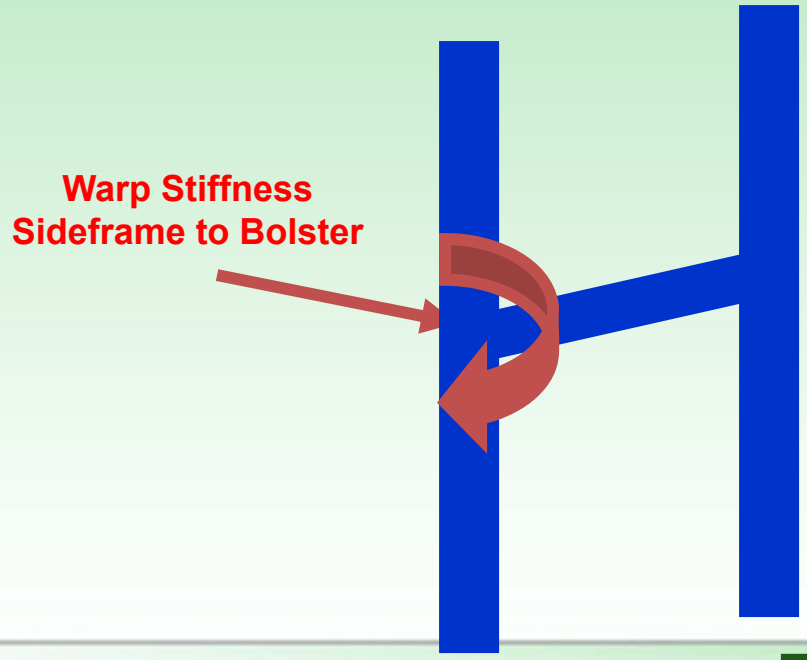


Lateral Secondary Suspension Elements of Typical Transit Car Showing Damper and Air Spring.

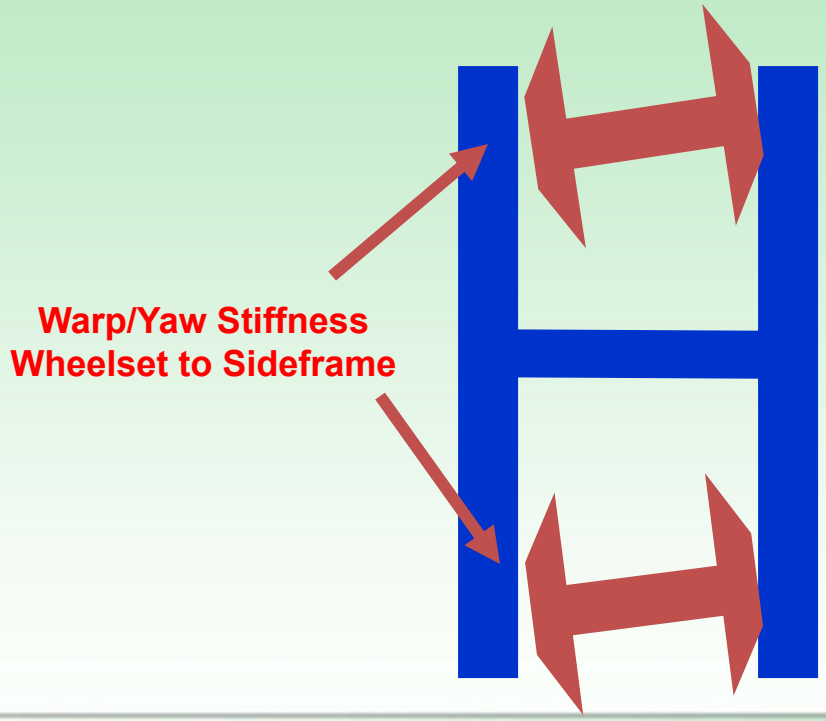
Yaw/Warp Suspension



Yaw/Warp Suspension



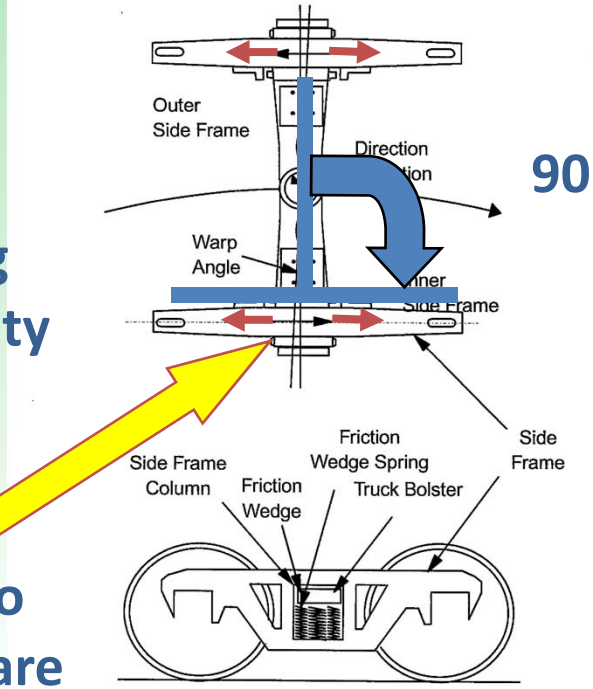
Yaw/Warp Suspension



Yaw/Warp Suspension

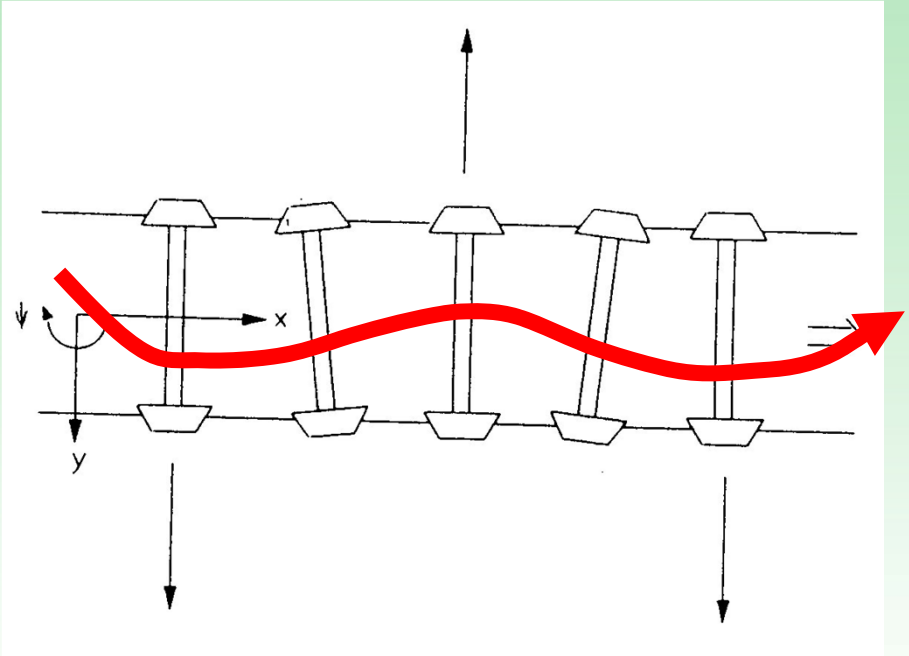
- Yaw/Warp Stiffness influences two primary responses
  - Hunting (high speed stability)
  - Truck Warp (Curving)
- Freight Cars depend on the friction wedge system for warp stiffness
- Passenger cars are normally rigid frame possessing high warp stiffness, but typically possess lower yaw stiffness

Truck Hunting
Lateral Instability



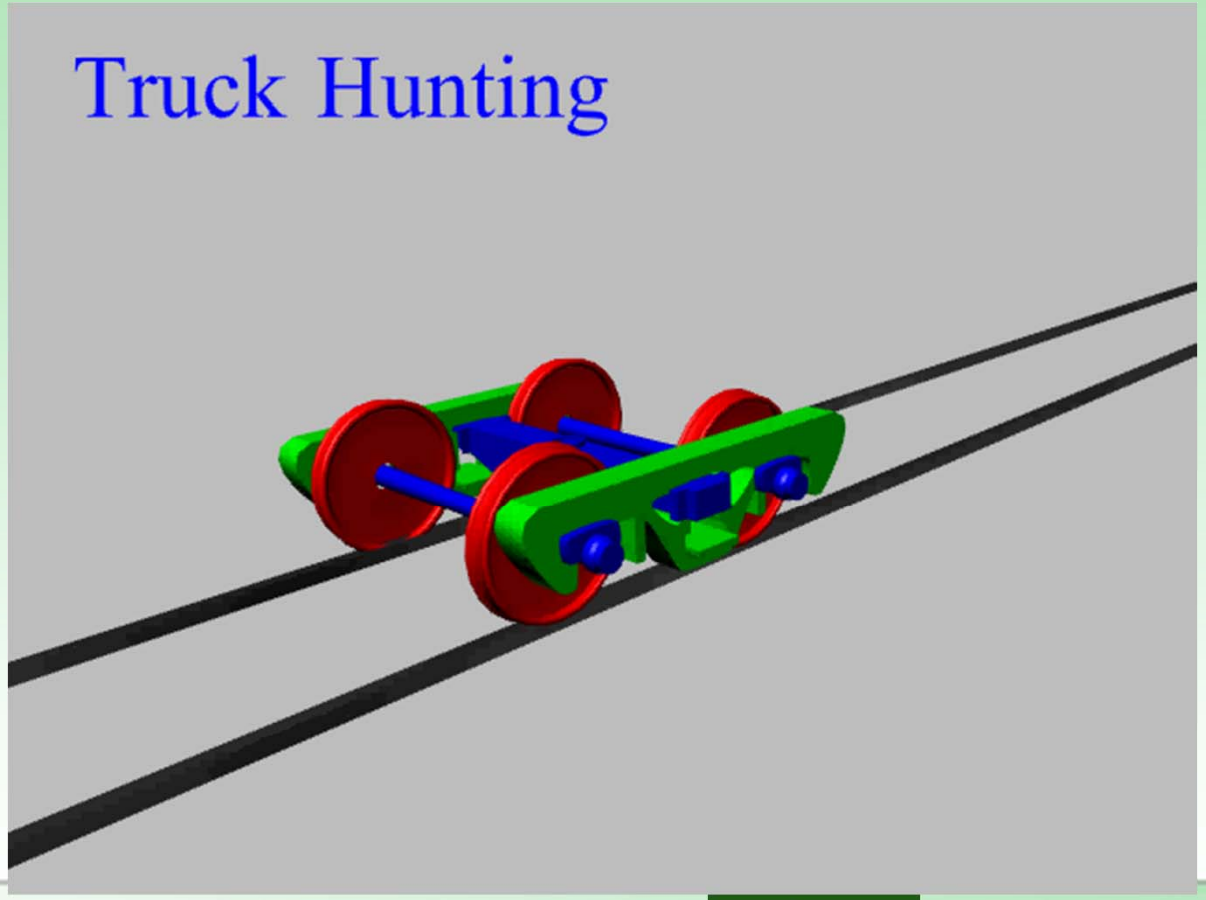
90 Degrees

Wedges Help to
Keep Truck Square

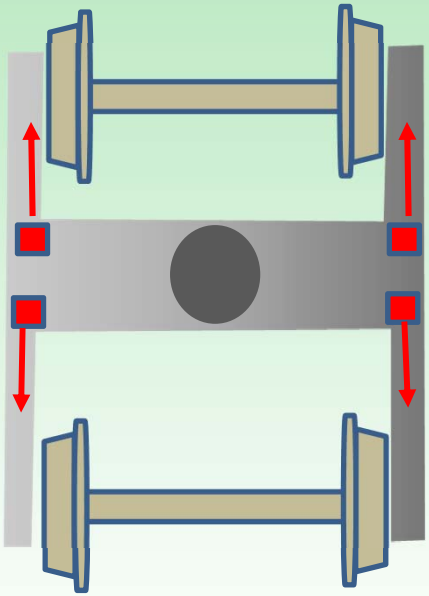


Hunting Oscillation of a Tapered (Conical) Wheelset

Truck Hunting

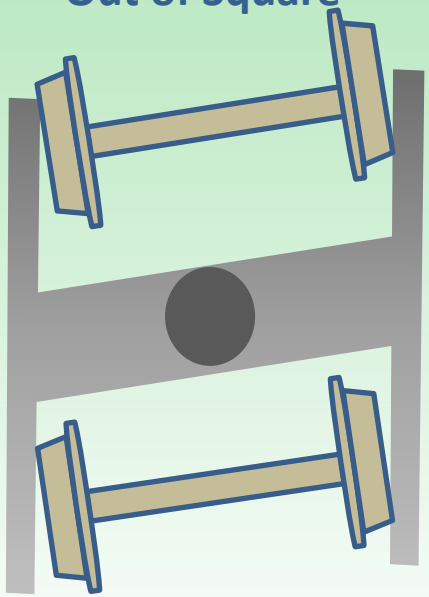


Truck Stable
Remains Square



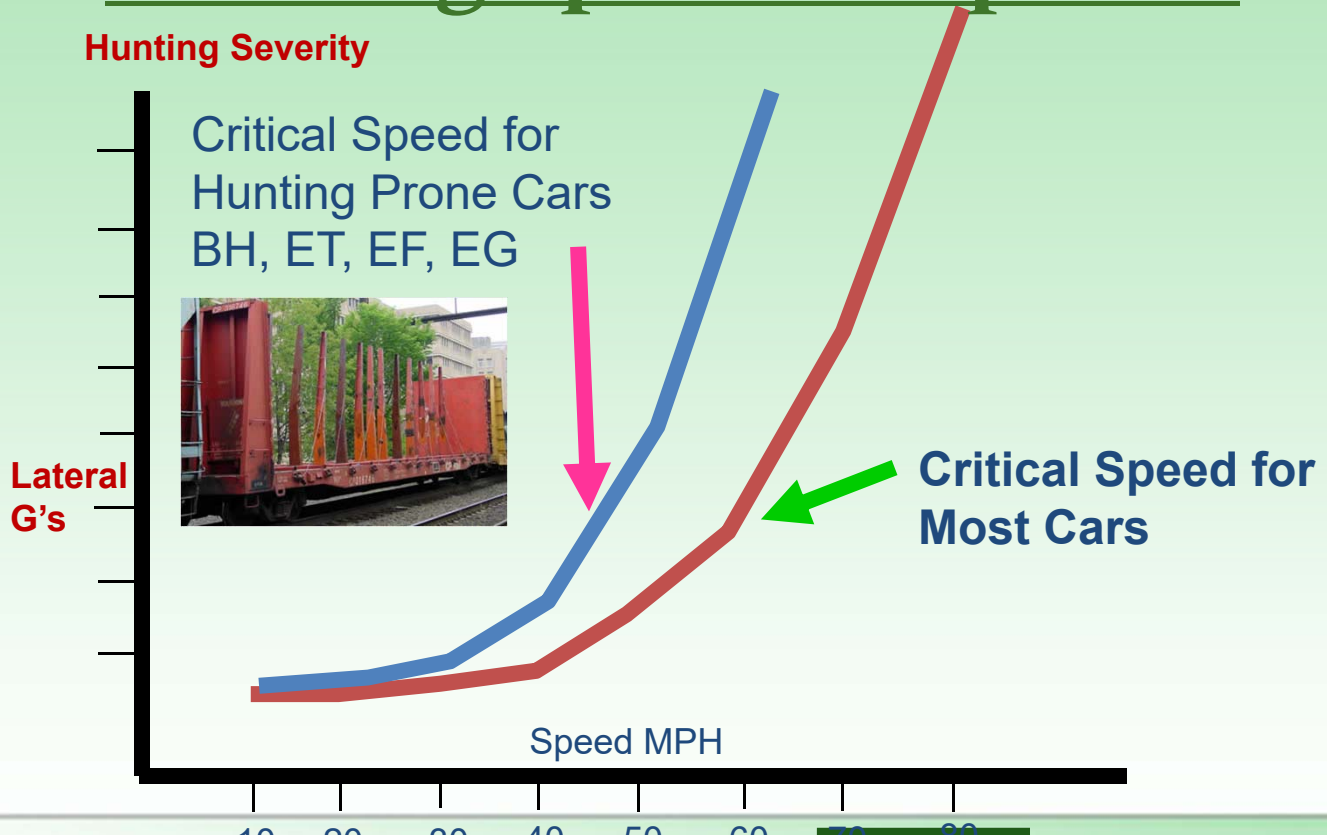
Friction wedges
provide squaring force

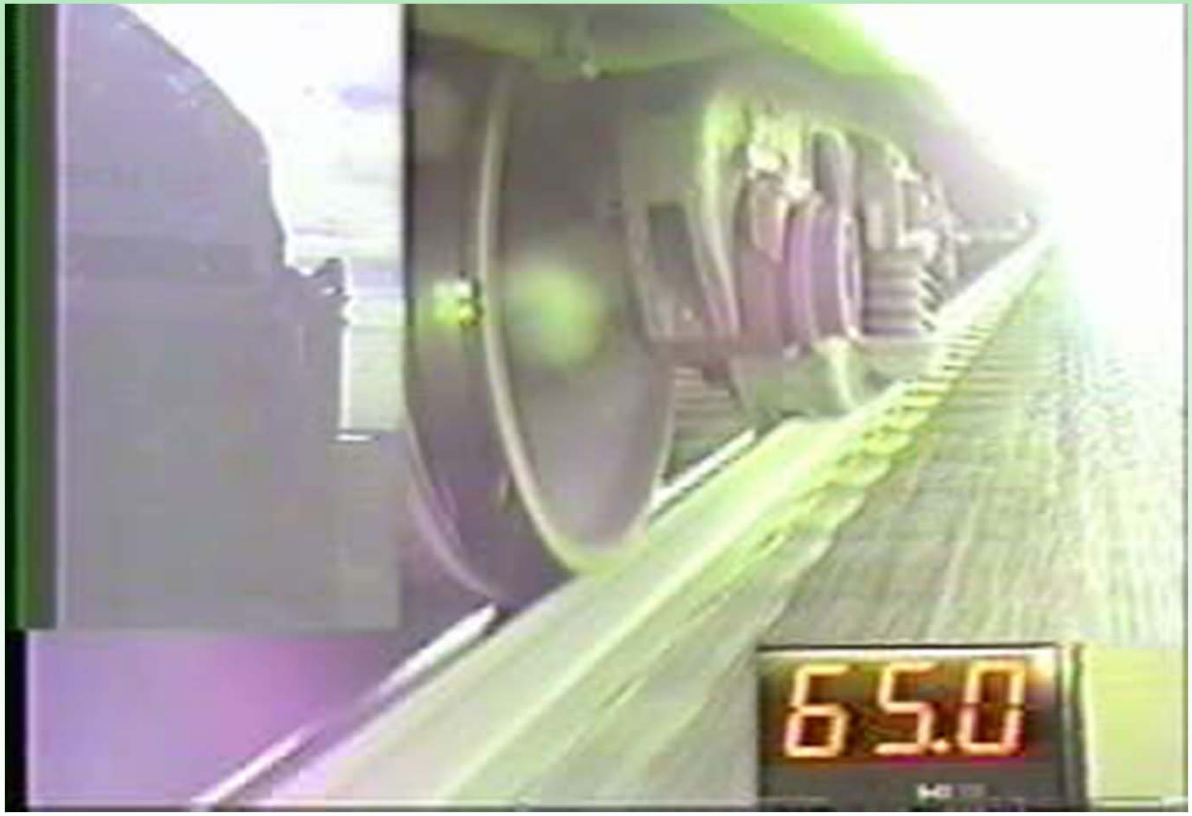
Truck Hunting
Bolster Sideframe
Out of Square



Friction wedges worn
providing no squaring force

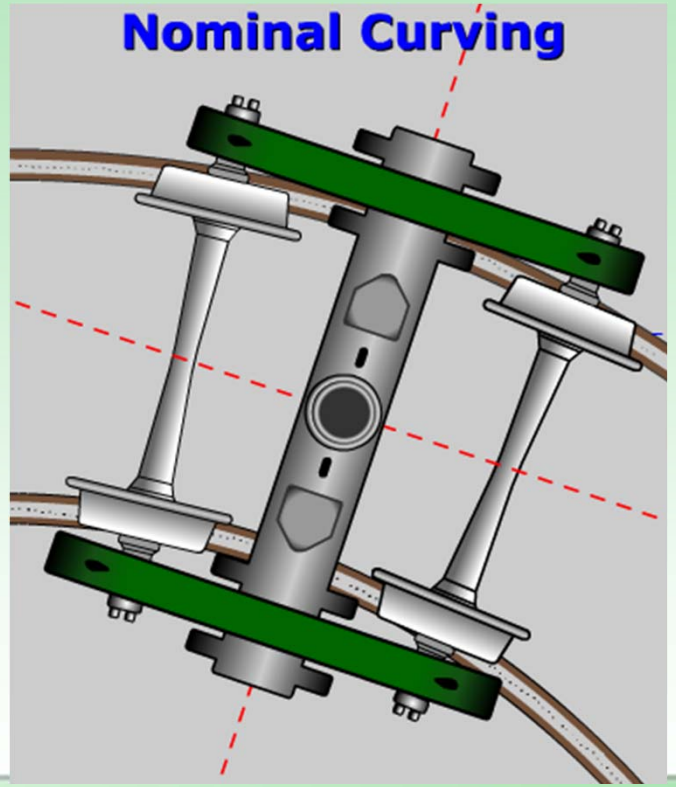
Hunting Speed Response



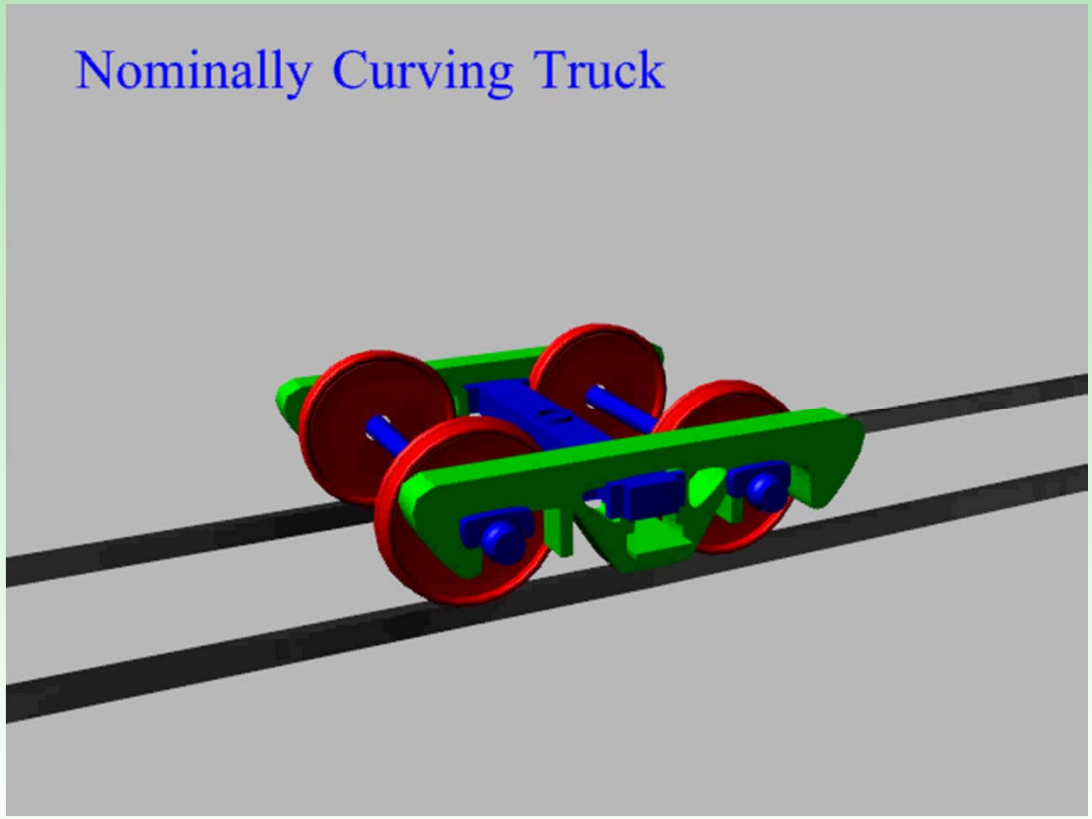

65.0

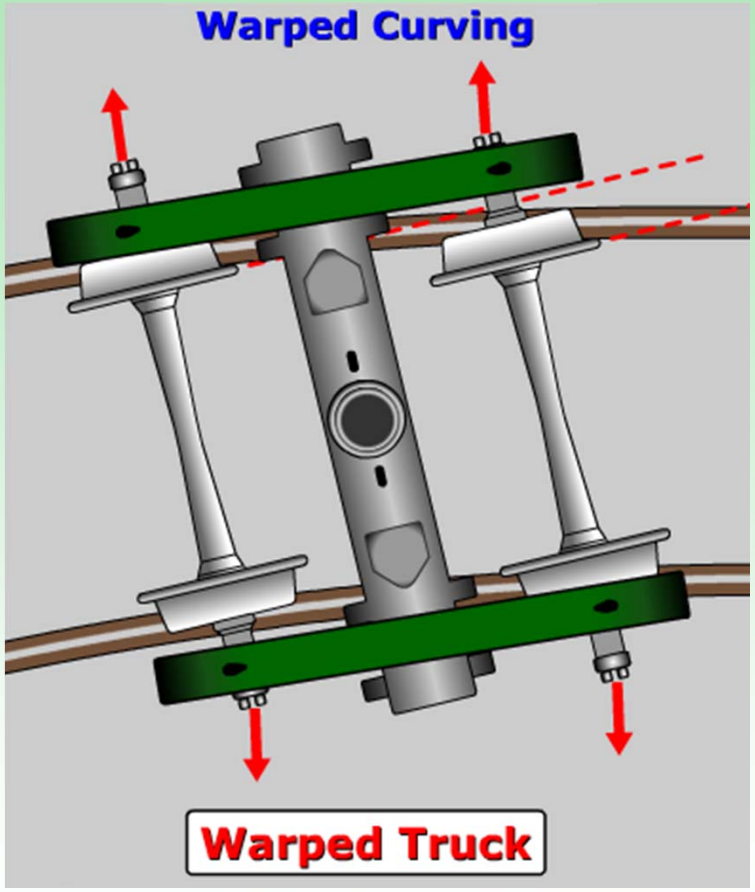
Truck Warp Restraint

Ideally, a truck should remain “Square” during curving to allow radial alignment of wheelsets with curve

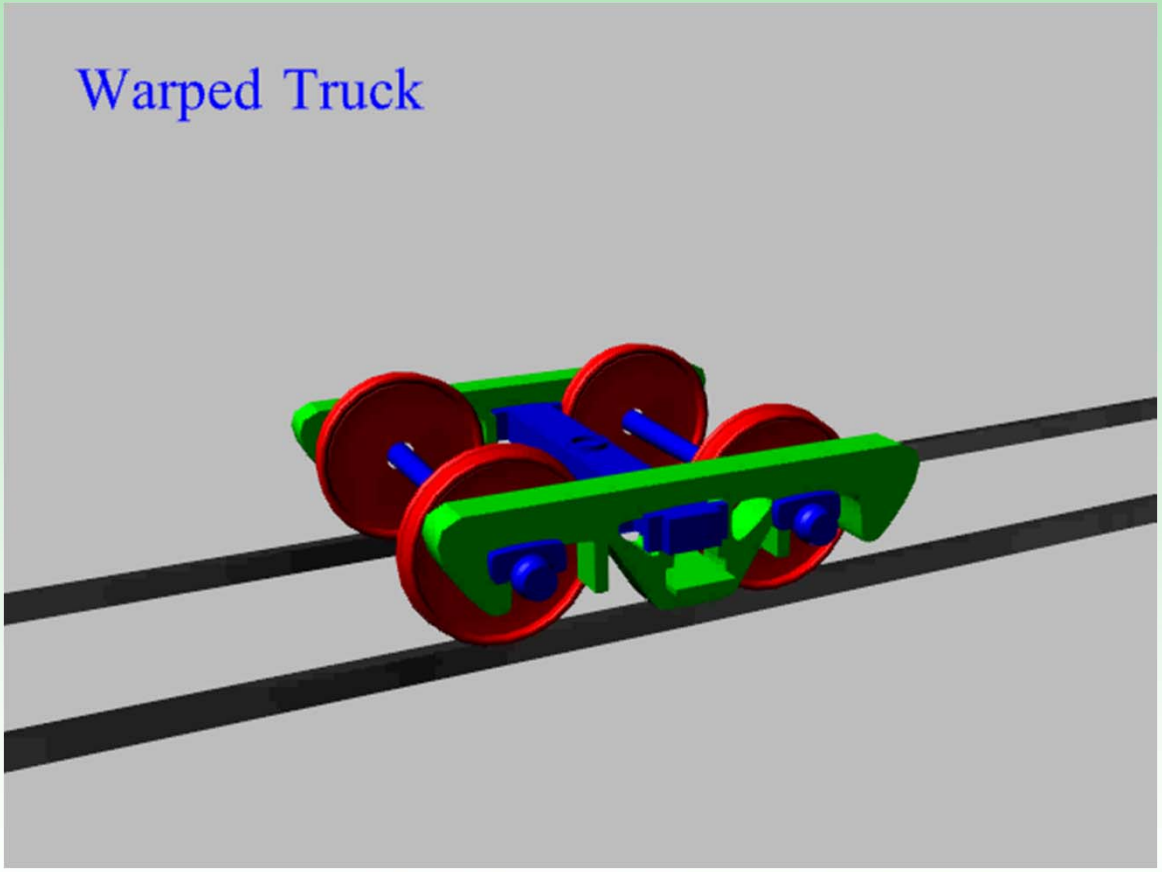


Nominally Curving Truck



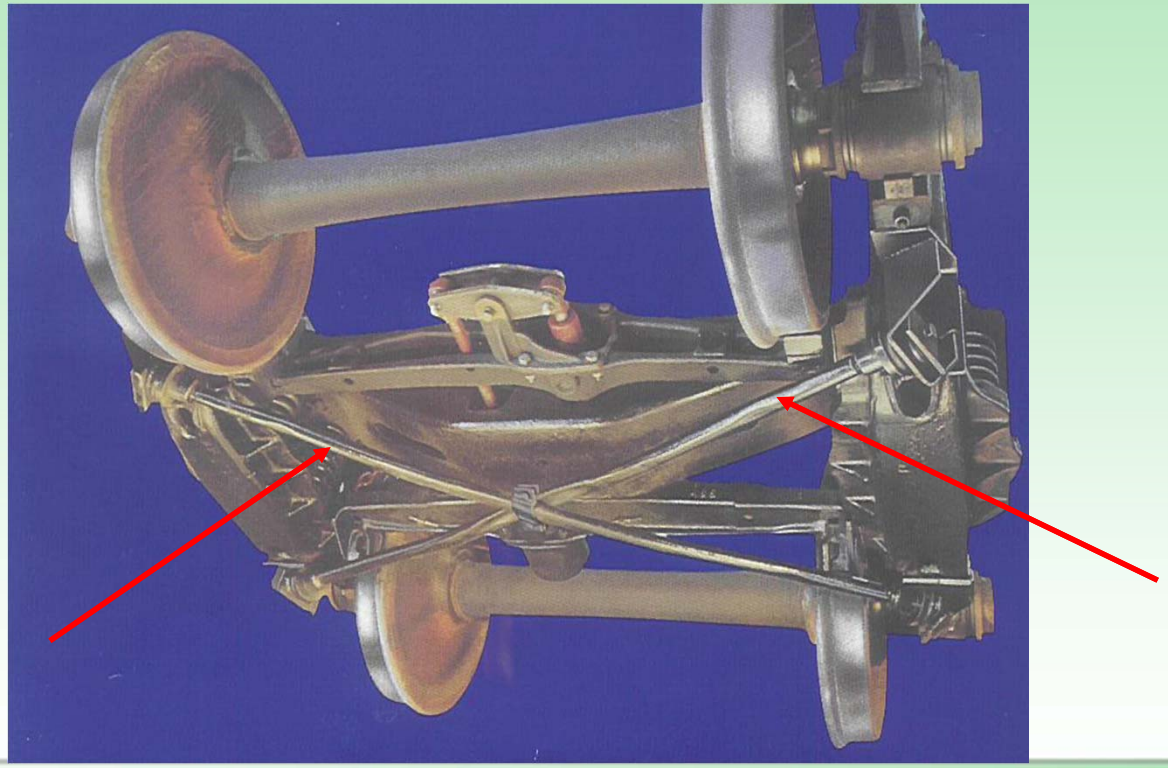

Warped Curving
Warped Truck

Warped Truck



Barber Frame Brace Truck

Frame Bracing increases the warp stiffness of the truck improving both high speed stability and curving.



The End

Truck Suspension Basics